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WORKS ORGANIZATION AND MANAGEMENT

BY

EDGAR J. LARKIN

LECTURER IN FACTORY MANAGEMENT AND MACHINE DESIGN
AT DERBY TECHNICAL COLLEGE AND REPTON SCHOOL

FOREWORD

BY

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FOREWORD

Administration, rather than invention, may be said to be the major and urgent problem facing modern industry. Individual concerns have grown enormously in size. Many, extending their activities from winning raw materials to marketing the product, have greatly increased in complexity. These changes alone would put a premium on managerial ability. But this is not all; the secret of productivity has, within the last few years, been discovered and exploited.

The idea is simplicity itself. On the one hand, as exemplified in the biscuit industry, the manufacturing process must become continuous and automatic; on the other hand, especially in many engineering works, production has to be split into a multitude of single operations, so correlated that each part ultimately fits exactly into the whole assembly.

Now consider what this means in practice. The article must not only be designed to function efficiently, but also must be *planned* so that it may be analysed into an orderly sequence of simple operations or processes. Machines must be chosen, if need be designed and constructed, to carry out each operation speedily and accurately. The layout of the works themselves must be such that there is a proper flow of materials; the machines must in number and arrangement be such that the right number of parts is produced to time, nicely balancing the various outputs. Since in this new industry the human element is linked to the machine— the operator's skill must be adjusted to it and his work-rhythm must beat to its time— the selection and management of works personnel is of fundamental importance.

One can thus easily understand why the number of trained technicians employed in modern businesses has risen considerably. Not so widely recognized is the fact that an entirely new type of executive personnel is in demand. Of those who enter industry now, a much smaller proportion is engaged in design or investigation of the product; by far the greater number is required to design and organize production. It is quite safe to say that ninety out of every hundred young technicians entering on an industrial career will, in the end, be found on the staff of the works executive and not, as formerly, in the design office. They will become managers. The demand is for managers, but for managers selected from those who in ability, training, and intelligence are in no way inferior to those who pass on to work out more theoretical problems. It is one of the discoveries of modern industry that brains are needed as urgently in the factory as in the design office or the laboratory.

Doubtless administrative ability, no less than the mathematical, is a gift, but both equally need instruction and both must be efficiently trained. Thus technical education is set a fresh task. Experience and experiment over a century have provided a basis for the sound education of chemists, physicists,

and technical designers, but for the training of managers there is little guidance either as to teaching methods or the content of an educational scheme.

It is when the need for such novel courses arises that the technical colleges most feel the benefit of the system whereby they enlist expert industrialists on their staffs as part-time lecturers. Among such is Mr. Larkin; and, when a while ago I entrusted him with the task of providing courses in factory management, I realized as never before how a ripe practical training and experience in responsible executive positions, combined with teaching experience, could make a new subject of this type successful and realistic.

Among the fruits of his labours in this direction is this book on factory management. When Mr. Larkin showed me his manuscript, I saw at once that in a practical fashion he had covered the whole of the factory system from lay-out to sales, from design to machines, from production planning to the tool room, with all those charts, schedules, tables and calculations by which such finely adjusted organization is achieved. Nor has he neglected questions of personnel. Selection, health, and well-being of staff are matters of which the importance increases daily. More vital even is the question of education of young entrants, and in this connection his own system of workshop training, worked out carefully in a large concern over a period of years, should, with its novel method of control, appeal with special interest to those who have the task of supervising the careers of apprentices. Here then is the tale of just what is done in actual factories and how it is done.

Such a textbook the advanced student has long needed. Yet the foreman, the young executive and even the more responsible manager should find it a help in daily problems. Certainly it is of value to those, such as I, who take an intense, if necessarily detached, interest in industry and the ways of industry.

W. ALFRED RICHARDSON

DERBY

PREFACE

Factory management is, as will be realized, an extremely wide subject with many phases. To condense the subject into a book of reasonable compass quite obviously creates difficulties, and therefore those sections which are more general in character and which I feel are adequately covered by other books have been abbreviated. More particularly does this apply to the work of the accountant, whose primary duty is, of course, to separate Capital from Revenue. The information which has been included concerning the accountant's activities may be regarded as that portion with which every engineer should be familiar if he is to be efficient in the carrying out of his duties.

A work of this kind, in order to be useful, must not only give an account of the arrangement but must show the means by which the management can effectively carry out its prescribed organization. Accordingly, an endeavour has been made to include the most acceptable forms, charts, and graphs to be used in the factory. Experience of more than twenty years in industry has proved to me that these are not a matter of minor importance. Indeed, not only do they require the utmost consideration if efficient operation is to be ensured, but they may be regarded as the key to the whole situation.

I take this opportunity of expressing my indebtedness to those colleagues who have so readily assisted in providing many useful data, to the several firms who have enhanced the utility of the book by kindly supplying photographs and other information on request, and to the British Standards Institution and *Engineering* for their helpful co-operation.

EDGAR J. LARKIN

Littleover
Derby

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WORKS ORGANIZATION AND MANAGEMENT

CHAPTER I

THE MANAGEMENT FUNCTION

Definition of Terms

LET us begin by defining the two words "organization" and "management." On referring to the Oxford Dictionary we find that "organization" is described as "the condition of being organized; the mode in which something is organized; systematic arrangement for a definite purpose." The interpretation of the verb "to organize" is "to form into a whole with interdependent parts; to give a definite and orderly structure to; to systematize; to arrange something involving united action." Accordingly, the meaning of "organization" when applied to a factory may briefly be described as the systematic arrangement of buildings, equipment, and individuals in order to achieve a definite objective. It is the actual method of management, the direction and control of all the factors involved in manufacture, and the plan by which individuals work separately and collectively to accomplish a given task.

Again using the Oxford Dictionary, we find that "management" is defined as "the action or manner of managing; power of managing; administrative skill," whilst the meaning of the verb "to manage" is "to control the course of affairs by one's action; to control the affairs of an institution, state, etc.; to administer finance, provisions, etc.; to deal with carefully."

Works management is therefore the skill with which a factory is controlled and operated. It is the invisible force which is behind the life of the factory. Finance, equipment and materials may be organized, and employees may carry out their duties, but unless systematic management directs the operations, their performance may become so uneconomical as to cease entirely. It is only by the influence of the management function that money, materials, men or machines can produce any result.

Administration

Next, let us consider for a short time the structure of the enterprise, after which we shall better appreciate the functions of the various executive heads.

At the supreme head of the business there is, of course, the owner. Ownership may be invested in an individual, in a partnership, or in a corporation, the latter being either a public body or else represented by shareholders. There is a clear distinction between

ownership or corporate activities and purely operating ones, and the accompanying diagram (Fig. 1) will serve to show the usual line of demarcation.

In a firm of any magnitude the position of the chief executive officer, usually styled the general manager, is by far the most important and most onerous of all. It is for him to interpret carefully the policy of the administration. This will include the establishment of the business, the co-ordination of finance, production, and distribution, the settling of the extent and form of the business, and the provision of ultimate control and co-ordination of executive effort. Consequently, as the operating head of the enterprise the chief executive officer must convey this policy to all whose function it is to operate the business. This is an arduous task, making it particularly desirable that a minimum number of individuals should report direct to him, thereby allowing adequate time for policy development.

It will be as well to remember that at the present time there is a decided tendency for commercial undertakings of every description to amalgamate, thus cheapening production costs chiefly by concentrating manufacture of certain products at particular factories, reducing competition and obtaining a monopoly, and lowering overhead charges. This makes it increasingly important that the chief executive officer should be an individual of exceptional all-round ability. It is not enough for him to exercise authority—he must consciously influence the co-ordination of the thoughts and actions of those working under his authority. The role is a very difficult one, because the strongest of all human instincts is that of self-preservation, and there is an unconscious tendency for individuals to consider their own interests before those of others.

Systematic Management

Although systematic management includes the fixing of routine, its primary object is the planning of responsibilities. There must be some tolerance in this respect to meet the lack of uniformity in individuals, much the same as tolerances in dimensions are laid down to allow for permitted variations in workmanship. It is not always possible to replace one individual by another in receipt of much the same salary. It is frequently necessary to fit the job to the individual rather than the individual to the job.

With the expansion and growth of the engineering industry a science of works management has evolved which does not appear to follow any clearly defined lines of development. In all probability modifications have been necessitated by circumstances and immediate requirements. Indeed, many traditional practices may have been accepted without consideration of their continued suitability. Development of the equipment and operations, and perhaps even more so the size of the plant, has necessitated the application of scientific principles, not only to the paramount question of costs but also to the division and delegation of responsibility which

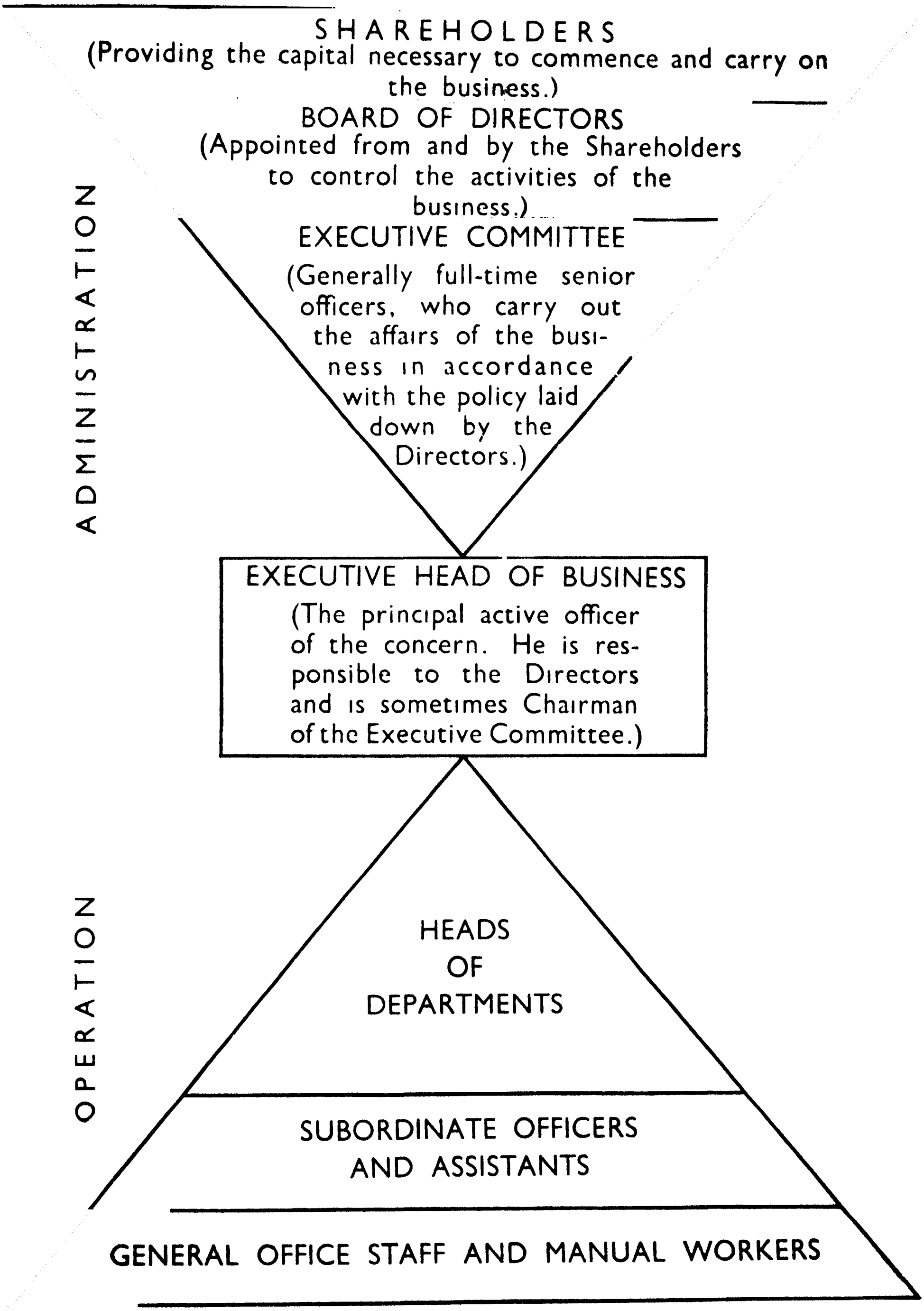


FIG. 1. CHART ILLUSTRATING CORPORATE FORM OF ORGANIZATION

otherwise might exceed the limits of individual ability.

It need hardly be said that a mere system is insufficient. Morale and loyalty must be encouraged. If men are regarded as cogs in a machine they will certainly not be anything more. Every employee, no matter how humble his position may be, has a share in the success of the whole enterprise, and the co-operation of all the staff must be secured, and their skill and initiative utilized to the fullest extent.

Those in authority should always remember that boredom kills efficiency. It is, therefore, a function of good management to make the work as interesting as possible. Those whose work is of a routine character should be encouraged by alternative interests, and at all times the door to promotion should be kept open. The importance of the latter cannot be over-estimated—everyone should be given an opportunity for improving his position.

Briefly, the requirements of management are eightfold—

(1) A practical knowledge of the industry.

(2) Personality, i.e. self-confidence, energy, foresight, and initiative.

(3) Broadmindedness, i.e. a receptivity to new ideas.

(4) Understanding of human nature, i.e. impartiality, fairness, and consistency.

(5) Leadership, i.e. ability to obtain co-operation and co-ordination with discipline.

(6) A keenness for efficiency.

(7) A distaste for waste.

(8) Ability to analyse reports and extract important information.

The success or failure of any organization depends ultimately on securing the fullest co-operation of the heads of sections, the foremen, and through them all the employees. Management must therefore (1) always try to look at things from the employees' standpoint, (2) make the fullest use of everyone's abilities, and (3) supply whatever information may be necessary to all concerned.

A faulty organization results in executives having to struggle with a mass of detail; thus time and material are wasted and orders are not fulfilled punctually. On the other hand, a good organization allows executives freedom to think constructively and to devote attention to essential matters, and it secures a smooth flow of production and ability to deal with unexpected demands.

Types of Organization

There are three recognized forms of industrial organization—Military, Functional, and Line and Staff.

Let us consider each of these types.

1. *Military Organization.* In this type of organization there is a direct flow of authority from the head of the firm to the departmental chief in charge of particular officers of the business, and from these officers to the whole of the works. The apparent simplicity of the scheme, which is illustrated by the accompanying example (Fig. 2), is not consistent with modern requirements. A departmental chief is responsible for everything

within his department. His duties are, therefore, extremely varied, and consequently it is very difficult to secure a suitable man when starting a new business on a large scale.

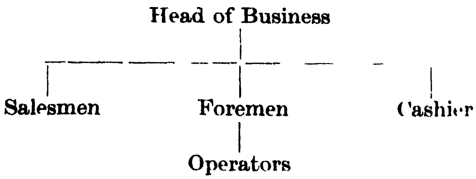


FIG. 2. MILITARY TYPE OF ORGANIZATION

To take an example, we have a machine shop foreman responsible for the following—

(1) The successful running of the entire shop.

(2) Layout of equipment.

(3) Instructions to and the training of men.

(4) Planning and progressing of work.

(5) Discipline, time-keeping, and records.

(6) Encouragement of loyalty and enthusiasm.

It is a task which has no definite limits, and consequently cannot be accomplished by one man. The foreman is not trained for all these duties, but is usually selected for ability in one or two directions, which is no guarantee of equal ability in others. He is therefore compelled to leave much to his subordinates, even though it may not be the practice to delegate specific duties.

Dr. Frederick W. Taylor, who has been described as the father of scientific industrial organization and management, and who laid its foundations between 1880 and 1890, gave the following ten qualities of a well-rounded man—

(1) Brains.
(2) Education.
(3) Special or technical knowledge.
(4) Manual dexterity or strength.
(5) Tact.
(6) Energy.
(7) Grit.
(8) Honesty.
(9) Judgment or common sense.
(10) Good health.

He rightly states that a person possessing three of the above qualities can be hired at any time for a labourer's wage, while a combination of four of these qualities demands a higher wage. Anyone with five such qualities becomes hard to find, and those with six, seven or eight are very rare indeed. With this conception, Dr. Taylor enumerates, as follows, the duties which a foreman in charge of a section of a machine shop will be called upon to perform under the military system, and the knowledge or qualities demanded of him on that basis—

First: He must be a good machinist; this attainment alone represents years of special training, and limits the choice to a comparatively small class of men.

Second: He must be able to read drawings readily, and have sufficient imagination to see the work clearly before him in its finished state. To do this he must at least have a certain amount of brains and education.

Third: He must plan ahead and see that the right jigs, clamps, and appliances, as well as proper cutting tools, are available and are used to set the work correctly in the machines and

cut the metal at the right speeds and feeds. This necessitates ability to concentrate the mind upon a multitude of small details, and take pains with little, uninteresting things.

Fourth: He must see that each man keeps his machine clean and in good order. This calls for the influence of a man who is naturally neat and orderly himself.

Fifth: He must see that each man turns out work of the proper quality. This requires the conservative judgment and honesty that are the qualities of a good inspector.

Sixth: He must see that the men under him work steadily and quickly. To accomplish this he should himself be a hustler, a man of energy ready to pitch in and infuse life into his men by working faster than they do, and this quality is rarely combined with the painstaking care, the neatness and the conservative judgment demanded as the third, fourth, and fifth requirements of a supervisor.

Seventh: He must look ahead over the whole field of work and see that the parts go to the machines in their proper sequence, and that the right job gets to each machine.

Eighth: He must, at least in a general way, supervise the timekeeping and fix the piecework rates.

Both the seventh and eighth duties call for a certain amount of clerical work and ability, and this class of work is almost always repugnant to the man suited to active executive work, and difficult for him to do; and the rate-fixing alone requires the whole time and careful study of a man specially suited to its minute detail.

Ninth: He must discipline the men under him, and readjust their wages; and these duties call for judgment, tact, and judicial fairness.

Tenth: He must enjoy good health without which it is impossible for an individual to devote his energy wholeheartedly and efficiently to the daily task which lies before him.

This enumeration of the duties of a supervisor by Dr. Taylor was the first real analysis of the military system supervisor. This analysis still holds good except that many present-day leaders would not consider that "hustling" and "pitching in" infuse life into people, as suggested by Dr. Taylor in his sixth point. The personality of a supervisor should create harmony and he should lead his staff rather than "hustle" them in order to achieve the best results.

It is at once clear that the duties which the everyday supervisor is called upon to perform under this system demand that he should possess a large share of the qualities of the well-rounded man to whom reference has previously been made. Dr. Taylor genially states that anyone possessing all the qualities would not be a foreman or supervisor but the works manager!

2. *Functional Organization.* The work of management in this type of organization is analysed and distributed to individuals each of whom is responsible for the performance of one particular function, or at any rate those functions which require essentially the same qualifications, thus permitting a concentration of effort. With such an organization it will be appreciated that the operator will

come into contact with a number of foremen instead of one, although these functional foremen will not necessarily spend equal times with him. The system is comparable to specialist masters in schools.

The chief advantage of a system of functional organization is that in a comparatively short space of time it

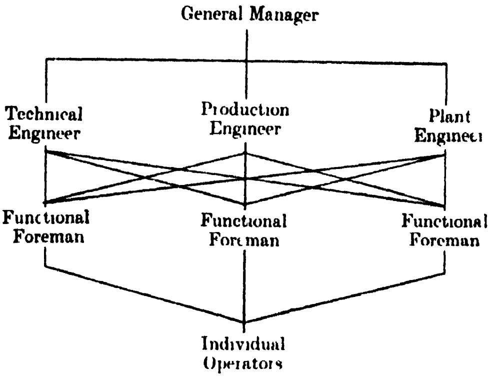


FIG. 3 FUNCTIONAL TYPE OF ORGANIZATION

is possible to train men adequately to perform the functions demanded of them. A glance at the duties of the functional foreman will show that he is not required to have over four or five of the ten qualities of the well-rounded man.

The system is illustrated in the accompanying example (Fig. 3).

Functional organization has not been fully adopted for one or more of the following reasons—

(*a*) It is cumbersome and expensive.

(*b*) There is a tendency to evade responsibility.

(*c*) The teaching of "efficiency" is not very popular as it tends to ignore individuality and repress experience and originality.

(*d*) It is unsatisfactory to attempt to "serve two masters."

(*e*) Close attention to details is necessary, broader aspects and larger factors not being given due consideration.

The main development of functional organization has been in the direction of functionalized departments working through a single foreman. In other branches of the business, apart from foremanship, considerable departures have been made from the original military idea with its improvements of adequate supervision.

3. *Line and Staff Organization.* This system is a combination of the military and functional types of organization. It develops the best possibilities of both and does not have the faults of either. It has for its foundation the joining of the functional idea with the direct flow of authority exercised in the military organization. That is to say, the line and staff scheme combines the necessary flow of authority from top to bottom, as in the case of the military type, with side channels of authority flowing out from the main stream at different points in the form of functional or staff departments. These staff departments have not only fixed responsibilities, but definite supervision over other sections of the organization. Directions from these departments must be observed by other co-ordinate departments and by subordinates in the same manner as if the orders had come from the head of the organization or from those immediately responsible to him. The authority of the staff department is supreme in its particular field of operation, though it may always be modified or its responsibilities changed

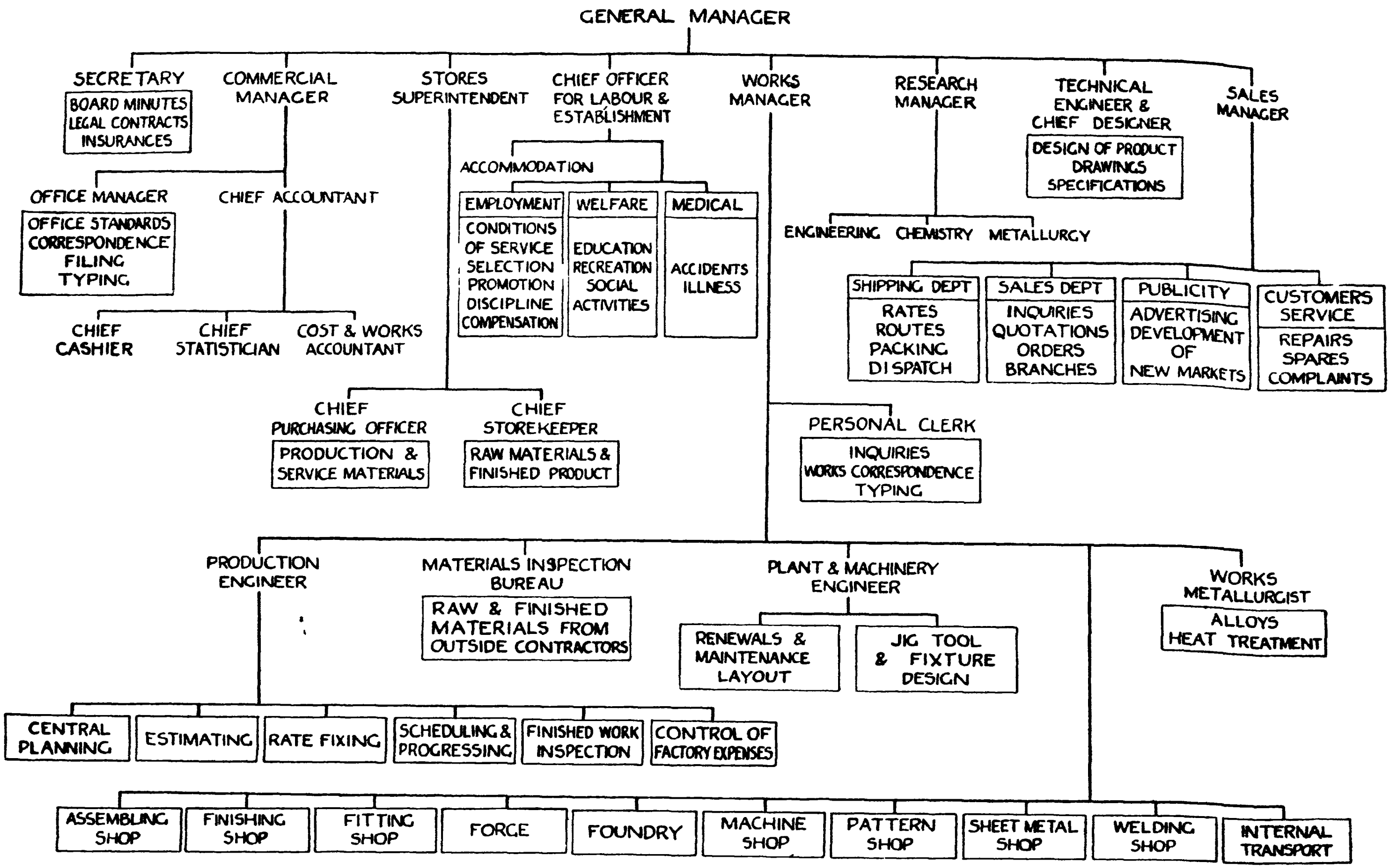


FIG. 4. MODERN ORGANIZATION FOR ENGINEERING FACTORY

through conference with higher authority.

To clarify the distinction between a line man and a staff man, or a line department and a staff department, a basis for discrimination may be given. A line man is one whose work deals with more than one phase of his division of the business, and who has "productive" workers under him. A staff man deals with one particular phase of the business, or, if his work be of a general character, he does not control any "productive" workers. The usual functions in any business are as follows—

(1) Designing.
(2) Purchasing and Storekeeping.
(3) Manufacturing.
(4) Accounting.
(5) Selling.
(6) Labour and Establishment.

Each department has supremacy in its own particular domain and its responsibility is clearly defined. There is, however, mutual help amongst the departments without any overlapping of duties. The author's idea of a sound line and staff organization, suitable for an engineering factory, is shown in Fig. 4. Whilst it is recommended that such a management or organization chart should be freely circulated to all responsible assistants within the organization, it should be remembered that these charts are only pictures of the organization and not the organization itself. The charts cannot portray the pulsating activities of the organization, nor can detailed duties be shown. In spite of this they are extremely informative, and it is recommended that they be supplemented by other charts representing individual departments and shops. An example is given in Fig. 5 which shows the organization of a millwrights' shop for a large factory.

Development of Organization

Every step taken in the development of the organization should be one of morale building and not morale destroying. In the former there is a full utilization of the skill, initiative, judgment, and training of each member of the staff, and development of these qualities in all, whilst everyone is encouraged to welcome responsibility and at the same time co-operate with others in the co-ordination of effort. In the latter the authority of the individual is restricted, initiative hindered, judgment overridden and action hampered by microscopic division of responsibilities. The conditions which tend to destroy morale generally develop gradually. Over-organization may be as harmful as under-organization, the former being good organization taken too far—hence the necessity for a proper balance.

A sound administration will pay adequate attention to each of the following rules—

(1) Everyone should be expected to do some thinking and show some initiative.

(2) Supervisors should have sufficient work to do—otherwise jealousies will be engendered and co-operation will be reduced, with a resultant conflict of authority.

(3) Seniority should not govern organization development. Some pre-

FOREMAN MILLWRIGHT

Senior Clerk (General correspondence and staff records)

Clerk (Correspondence, time-keeping, and returns)

Junior Clerk (Wages and Material documents)

Office Boy (General utility)

ASSISTANT FOREMAN

	Bricklaying Section	Gasfitting Section	General Labouring Section	Hydraulic Power Section	Joinery Section	New Work and General Maintenance Section	Saddlery and Rope Section	Water Main Section	Totals
Chargemen	1	1	1	1	1	1	1	1	8
Craftsmen	2	3	–	4	3	35	2	–	49
Semi-skilled	–	7	–	–	–	4	1	5	17
Labourers	4	–	28	–	–	–	–	–	32
Apprentices	–	–	–	2	2	10	–	–	14
TOTALS	7	11	29	7	6	50	4	6	120

TOTAL STAFF = 120

FIG. 5. TYPICAL ORGANIZATION OF MILLWRIGHTS' SHOP

determined scheme of promotion is very necessary, but education, intelligence, and general suitability for every position are of the greatest importance.

(4) The head of any department should be a real head and not merely a chief clerk. His ability and action should be the factor of safety which will enable the organization to stand the maximum strain upon it. He should have ability to control and supervise, to inspire and to enthuse.

It only needs a moment's thought to see that works management is a real science and that it becomes increasingly so day by day. It is, therefore, of first importance that those "at the top" should be completely satisfied that the fullest co-operation is being obtained between the various departmental chiefs and other officials. The slightest friction in the organization will result in inefficiency and may indeed be dangerous.

The smooth working of any organization is best secured by some form of advisory committee. Such a committee might include the works manager, the production engineer, the technical engineer, the plant and machinery engineer, the sales manager, and possibly foremen of the more important departments. Meetings should be held three or four times a year, when consideration will be given to (*a*) new designs, and modifications to existing ones, (*b*) relation between sales and production, (*c*) methods of cost reduction, and (*d*) routine operation, orders, and delays.

Extremely close co-ordination between the designing staff and manufacturing departments is essential if costs are to be kept down to a minimum. As a case in point every draughtsman should be well versed in shop practices, otherwise he will be unable to take full advantage of any new machinery and of new systems of manufacture which are continually being developed. Further, he should be in touch with the works estimating and central planning departments, and he will then better appreciate the relative cost of putting into practice different forms of design, and will be guided by such knowledge in the future. In short, he should not consider the drawing office his total sphere of operation but he should be allowed to make himself familiar with all aspects of production. Similar encouragement should be given to all other key grades.

Overloading of Duties

It is desirable that every officer in the concern, whether he be the works manager, a departmental chief, or a head foreman, should devote certain time to research and development in his own particular sphere. There is a tendency in industry to-day to overload the supervisors. As a result routine work takes up the whole of the available time, causing considerable waste of useful brain power, and consequently progress is seriously impeded. Such overloading of duties is indeed false economy.

Budget Control

Budget control fixes the limit of expenditure having regard to anticipated income. Its application represents the ideal financial control. Budgets can be prepared annually,

quarterly, or even at shorter intervals, the head of each department submitting his own budget and being held responsible for it. It thus becomes a personal matter for each chief, and will tend to stimulate his efforts. The general manager, or equivalent officer of the company, will prepare the final budget from the individual budgets submitted by departmental chiefs. It is not sufficient for the works to be operated on a total budget figure. This should be subdivided first into the various departments and then into different sections. The division of the budget should in fact be extended to the intelligent control of such expenses as small tool issues. Files, taps, drills, chisels, lead hammers, sponge cloths, and many other items each spell £ S.D. in capital letters. There should be a common basis for such items, and the average cost per employee in the various departments should be predetermined. Otherwise, though allowances may be made for different classes of work, the actual difference may prove to be out of all proportion to the nature of the work.

Budgeting should not be confused with costing, the results of which are history.

Provision of Charts

The utility of charts and graphs in portraying outstanding features associated with systematic management can scarcely be over-estimated. It may be said at once that no statement of figures has the same practical value as a graph when making comparisons. Graphs may be arranged on orthodox lines or in the form of a barometer. They can show various sources of income and expenditure, man-hours worked, output in tonnage or quantities, value of orders on hand and of those still outstanding, the number of staff absent, accidents and compensation paid, etc. Machine record, load, progress, and similar charts, in the form of the well-known Gantt chart, showing what was planned and what was achieved over a given period, make it possible for the executive to foresee future happenings with considerable accuracy. The underlying idea is to become chart- and graph-minded, and to plot some feature to a good scale which has not previously been plotted. It will open up fresh avenues of thought.

Technical Engineer or Production Engineer

Broadly speaking, the science of engineering may be divided into two sections—

(1) Design.
(2) Production.

It can be stated that the genius of engineering design and the genius of production engineering, moulded into one individual, is, in the light of present-day standards, a rarity almost to the point of extinction. The former requires a wide theoretical and practical knowledge of the industry, the latter requires a natural ability to organize and control men and equipment. Whilst a chief must of necessity be ready to cope with any subject, he invariably concentrates on his stronger points and leaves the rest to others who are, no doubt, as capable in other directions.

A young man who has received his preliminary training should decide which is his strong forte and develop it to the best of his ability and opportunities. An employer or a works manager should make it his business to find out the outstanding qualities of each member of his staff, and as far as possible give him every facility for developing those qualities—this represents real management, and is bound to benefit the organization.

The boss inspires fear; the leader inspires enthusiasm. . . . The boss says, "Get here on time"; the leader gets there ahead of time. . . . The boss makes work a drudgery; the leader makes it a game.

Quoted in The Times.

CHAPTER II

SELECTION OF A FACTORY SITE

THE choice of a factory site must always be regarded as a major problem by those responsible for such a task. It is an event which, if it occurs at all, will usually occur once in a lifetime, and is therefore of paramount importance. There are the pros and cons to be considered with every potential industrial site, and the plant engineer must rise to the occasion in the earliest stages as, once the site has been purchased and the factory erected, disadvantages which were not foreseen at the time when the site was bought may become only too obvious, and may represent a hidden expenditure which may exist for all time and must inevitably be reflected in the selling price of the product to be manufactured.

Preliminary Considerations

Before any site can be considered, some general planning of the proposed factory must be carried out. The work involved can be conveniently divided into four distinct categories—

(1) The determination of the floor space required for the manufacture of the product, plant services, stores, dispatch, warehouse, transport, administrative offices, and welfare activities.

(2) The determination of the actual dimensions and construction of the buildings required.

(3) The determination of the arrangement and relative location of the manufacturing and ancillary departments—an arrangement which must be done in a manner that ensures maximum economy in both capital and running costs.

(4) The determination of the open spaces required for natural light, light railways and roads, storage of material, and recreation.

Each of these four sections presents its problems, and the amount of time and thought to be occupied over each will vary according to the size and complexity of the proposed business. The more difficult problems will arise in those trades where many processes are involved, or in those involving several kinds or a considerable quantity of material. At the same time it must be admitted that big operations present their own difficulties where manufacture is to be carried out on a particularly large scale. What is essential in all cases is a very thorough and complete knowledge of the manufacturing problems of the industry for which a site is required. The same remarks apply equally if it is an extension or a partial reorganization of an existing factory which is contemplated.

It is perhaps hardly necessary to point out that the adoption of a layout at once limits the extent to which many of the requirements may be met. There is, of course, the question of providing for future extensions, a matter which should never be lightly passed over, yet the proposed layout will even sooner cause many questions

of construction to arise. Accordingly, the investigations which require to be carried out must also be extended outside the actual field of the manufactured product. Where a general engineering works is under consideration, embodying as it does patternmaking, foundry work, forging, plate work, fabrication, machining processes, fitting, erecting, and possibly other operations, it will require much more thought than one which will be concerned only with, say, machining and assembly operations. In some cases, as for instance in certain branches of the textile industry, fairly stereotyped layouts should be followed, and it is only when the reasons advanced are sufficiently sound that a departure should be made.

Layout Generalities

Floor Areas. The layout must, of course, be based on a detailed analysis of the manufacturing processes. In this connection, therefore, it is first necessary to determine (*a*) what shall be manufactured entirely in the factory, (*b*) what shall be purchased in the rough state and finished in the factory, and (*c*) what shall be purchased completely finished.

As soon as this has been done, the next step to be taken should be the preparation of a chart on the lines of that illustrated in Fig. 6, showing in correct sequence the function of each department forming the factory and the relation of one department to another. Using this chart as a basis the next stage is to determine the floor area necessary for each department.

It will not be unduly difficult to estimate for immediate requirements or even those of the near future, but to anticipate future developments in one department or another is much more difficult. The problem, however, is far too important to be left to chance, and it will be necessary to fix maximum and minimum areas, and to take the maximum areas into consideration in the design of the buildings. If this wise step is taken, future extensions will be proportionately inexpensive. What is outstandingly important is the proper balancing of departments for economical working. Whenever necessary, the approximate area required for any particular process can be determined by appropriate reference to existing plant at some other factory of similar type.

Ideal Layout

Finally, a block plan of what may be considered to be the ideal layout for the factory should be prepared. In this respect small paper templets, cut to sizes which represent the ground floor space of the different departments, are likely to prove most helpful in deciding upon the best relative positions.

The type of block plan required is illustrated in Fig. 7. This shows a suggested floor layout for a large works, the nature of which makes it adaptable for a wide range of engineering products. All the buildings can be considered to be single-story.

The important thing to remember always is that, wherever practicable, work should travel in one direction only, and that departments associated with each other should be adjacent.

This correct grouping of departments serves a twofold purpose, the more obvious being that the minimum of handling and transport is ensured

When such a plan has been prepared —and not before—investigations regarding a suitable site can safely proceed.

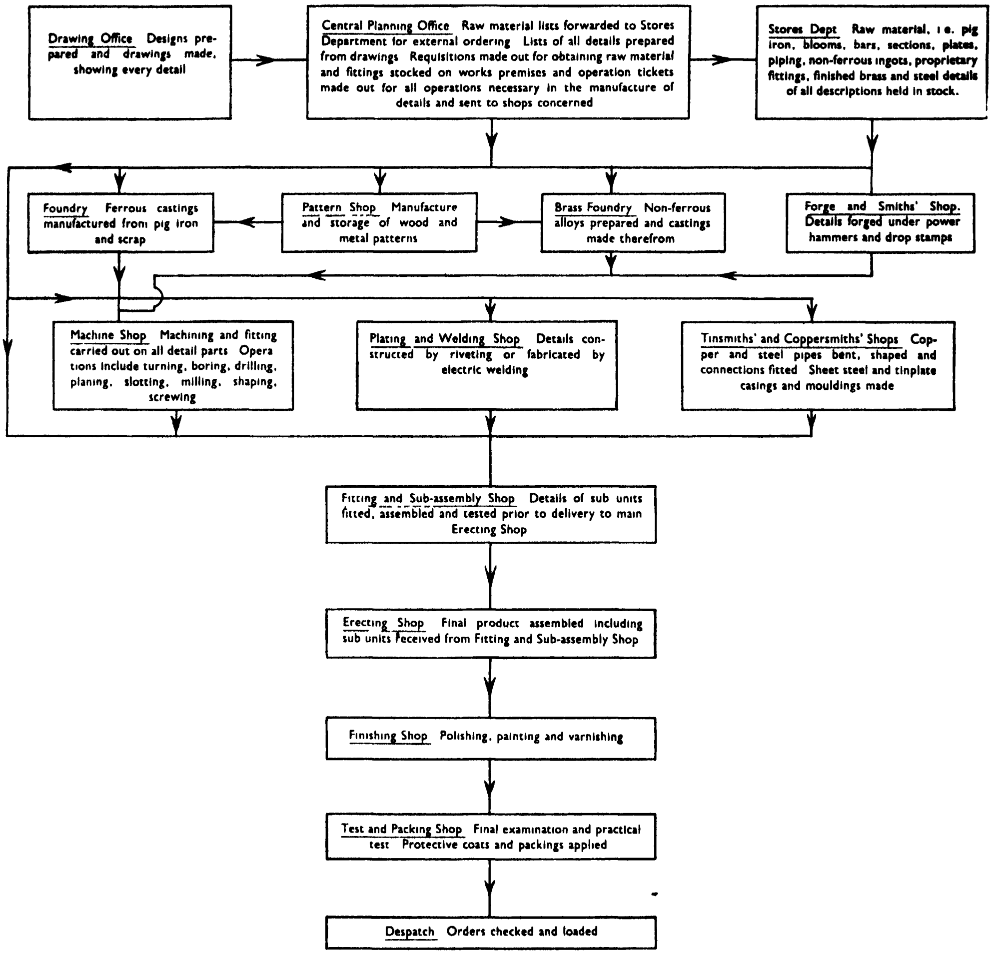


FIG. 6. CHART SHOWING DEPARTMENTAL RELATIONSHIP

within the works, thus eliminating considerable expense; the less obvious, but equally valuable, being that there is much closer co-operation between the heads of associated departments.

Site Questionnaire

Whether there is only one site under immediate consideration, or whether several alternative sites are to be considered, it is worth while to draw up a questionnaire at the outset

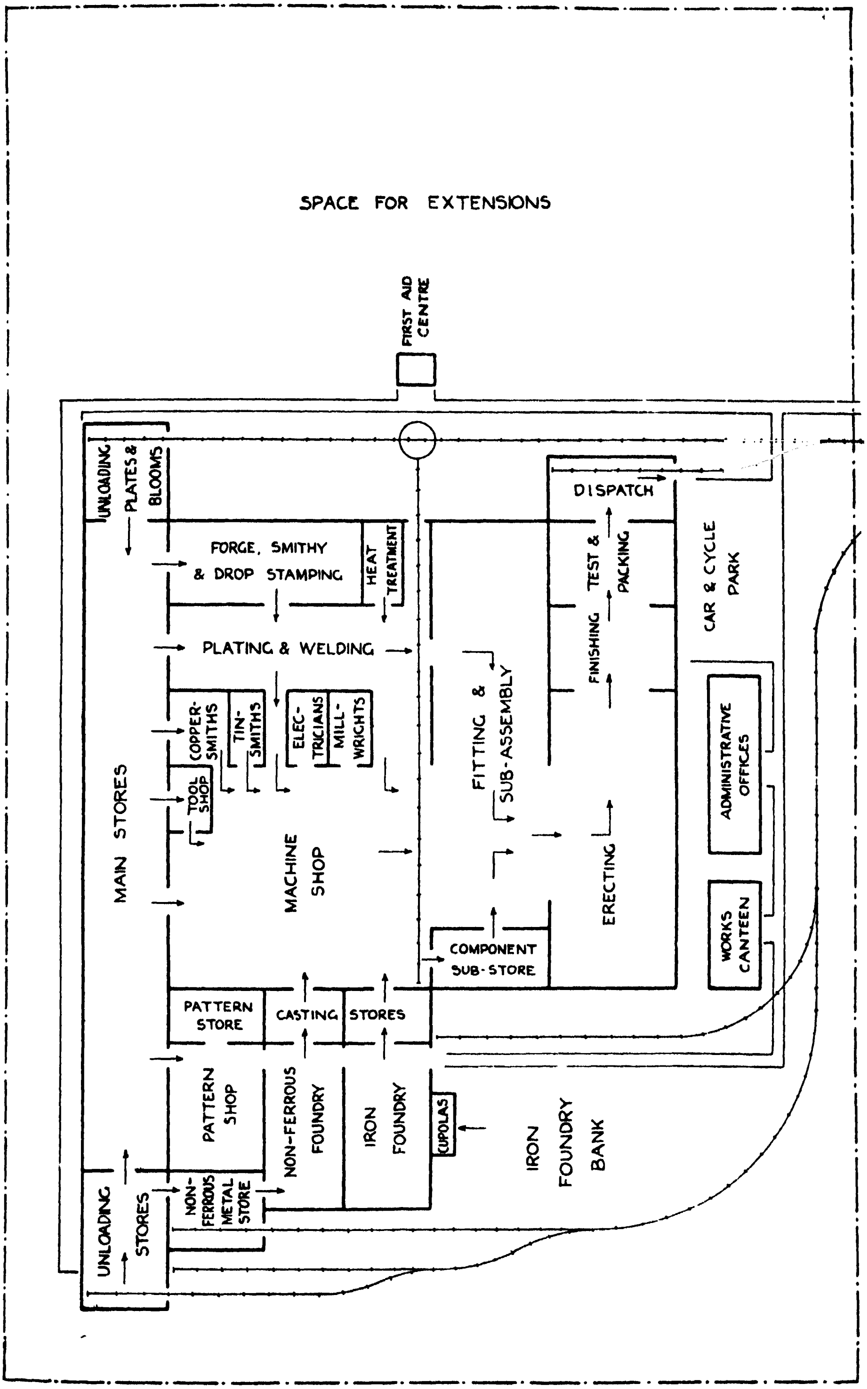


FIG. 7. BLOCK PLAN OF IDEAL FACTORY LAYOUT

and, without referring this to any other source, to give a considered answer to each question.

Such a questionnaire will provide the essential information for arriving at a decision, or for making a comparison between alternative sites.

(1) Is the site suitable in every way for the desired arrangement of the buildings?

(2) What is the nature of the subsoil?

(3) Can the external communications for the transport of material be regarded as satisfactory?

(4) Can the external communications for the transport of personnel be regarded as satisfactory?

(5). Will its area allow for any reasonable expansion of the works?

(6) Is gas available? If so, is the pressure suitable and the quantity sufficient? What is the price per therm?

(7) Is water available? If so, is the pressure suitable and the quantity sufficient? What is the price per 1000 gallons?

(8) Is electricity available? Is it D.C. or A.C., and what is the voltage? What is the price per kilowatt hour?

(9) What is the proximity of main storm water and soil sewers?

(10) Is the site freehold? Is it free of encumbrances such as rights of way? If not, give details.

(11) Can the site be regarded as one having appreciative value?

(12) What is the price of the land? Is it within the capacity of the undertaking to pay?

(13) Is the labour suitable for the industry?

(14) What are the wages costs of labour in the district?

(15) What is the ruling climate?

(16) Are floods or droughts experienced in the locality?

(17) What types of factory are in the neighbourhood?

(18) What are the local rates?

(19) Is the cost of raw materials into the works likely to be satisfactory?

(20) Is there any reason to think that the selling price of the finished article will be adversely influenced for any exceptional reason?

These factors, classified together, are embodied in the accompanying chart, Fig. 8, and it is necessary that each point should be fully considered.

General Survey

In order to obtain a plan of the site the most satisfactory procedure is to make an accurate survey of the land under consideration. If, however, more than one ownership is involved this may not be possible, nor would it perhaps be politic in such circumstances. The alternative is to obtain a large scale ordnance map which, of course, shows the contour lines.

Among the earliest questions to settle will be those of the site level and road gradients in conjunction with an examination of the subsoil and foundations. It should not be overlooked that a site which may at first appear to be suitable may involve such costly foundations that its purchase is altogether prohibitive.

The ideal foundation is unquestionably rock, but this may be so uneven that although excavation is a straightforward proposition at one end of the site, it may be a quite different problem at the other end. There is also the drainage of the site and construction of pipe tunnels with which to contend, and these are likely to involve some costly excavation work. So far as drainage is concerned, it is most desirable that the site level shall be favourable when compared with adjacent land, more especially when it is necessary to connect with existing public sewers and drains. Although a good hard clay foundation is generally regarded as satisfactory it may prove

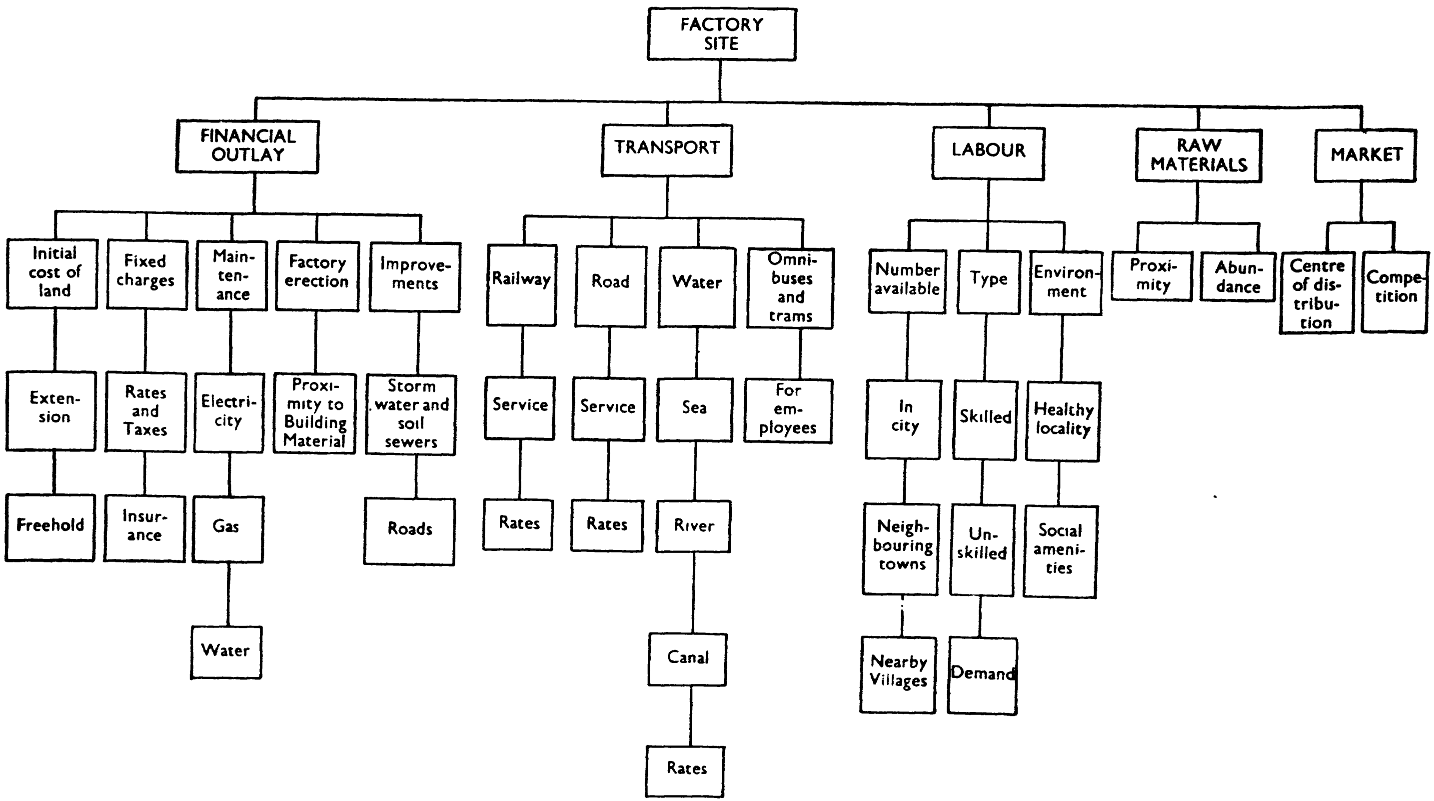


FIG. 8. PRIMARY CONSIDERATIONS IN SELECTING FACTORY SITE

treacherous under heavy loads, particularly if the underlying strata are slanting. It is also liable to crack badly during very dry weather, and to flow under the weight of dumps of heavy material during the winter months. Made-up land can never be recommended. Even though it may be of long standing there is always the possibility of the presence of deep pockets filled with rubbish. In the case of old works sites there may be the added expense of removing heavy foundations.

When the proposed site is in the region of a river no efforts should be spared before purchase is effected to ensure that at no time has the river or a tributary flowed through the site. This is best done by searching the local library or museum for old records and maps.

Unless there is a specific reason for deciding otherwise, most engineers will prefer a site which has a horizontal plane. If, however, one corner is at a lower level this is not necessarily a disadvantage. It may help to solve the drainage question or simplify shunting activities; it may be utilized as a tip for excavations or as a dumping ground for boiler ashes and other waste products from the factory.

Any land not immediately required can be used as a sports-ground, or possibly let for grazing. There may be times when it is not possible to purchase all the land desired, and tactful inquiry will elicit whether it will be available at some later date. It is possible that there may be legal or other obstructions preventing its purchase.

Title Deeds

The land to be purchased for a factory site should of course be confined to that which is freehold, but even so it is in every case desirable to search all the title deeds. Only in very extreme circumstances should leasehold land be considered. With such land the ground rent is usually very heavy and restrictions are numerous, the ground landlord often calling for a high standard of maintenance. Apart from this, it may some day be necessary to dispose of the entire plant, buildings and site, and leasehold property is not so readily disposed of as freehold.

Land which is subject to tithes or other permanent charges should be avoided; to say the least they are a fruitless source of expense.

Rights of way are often a continual source of annoyance if they come within the precincts of a factory. When once they have been established there is little prospect of their being removed or closed, and even though it may be suggested that a path which is occasionally used by only one or two individuals should be diverted a few yards, there is usually strong local opposition forthcoming.

Where public services, as for instance water mains and sewers, pass through the site, it is, of course, out of the question to build over them. Generally agreements have already been drawn up whereby the owners of the public services will make good any damage on the land due to burst pipes or similar occurrences. If, however, subsequent to the agreement being effected, any roads or tracks are

constructed by the factory owner over such services, the owners of the public service in question will not make good the road—they will only restore the land to the state in which it was when they laid their service. There is, too, the added inconvenience of not being able to use the road for lengthy periods.

Local Government Regulations

Local by-laws, particularly in areas where industrial sites have not previously been developed, are not always alive to modern factory building design. It is, therefore, particularly desirable that all local restrictions relevant to buildings, fumes, dust and wastes (both solid and liquid) should be carefully reviewed.

Local rates are an extremely variable quantity. In some instances the assessment is high with a low rate in the pound, in others the assessment is low but the rate in the pound is high, and the net result may be much the same. Districts where both the assessment and the rate per pound are high should be avoided unless there are distinct advantages in other directions.

Town versus Country Situation

The advantages and disadvantages of a town or city situation compared with a country situation may be summed up briefly as follows—

TOWN SITUATION

Advantages	*Disadvantages*
Transport facilities (convergence of railways).	Higher price of land.
Possibility of canal or river transport.	Developments usually difficult and expensive.
Plentiful supply of labour.	Taxation and municipal restrictions.
Educational facilities for children as well as for employees.	Higher cost of living involving higher rate of wages.

COUNTRY SITUATION

Advantages	*Disadvantages*
Land comparatively cheap.	Restricted supply of labour.
Wide choice of actual site.	Housing problems.
Facilities for future expansion.	Lack of social amenities restricting "emigration."
Lower rates and fewer restrictions.	Restricted travelling facilities.

There are cases of country sites which are suitable when acquired and which gradually lose their initial advantages (e.g. a factory is built in the suburb of a large town in order to obtain all the above advantages—the town is prosperous and extends, and the suburbs move outwards). In some cases the establishment of a branch works in another situation may yield a better return than an extension of the original factory.

External Transport

From the point of view of external transport the ideal site is one which has communication by railway, main road, river or canal, and in the case of some industries, the sea also.

A railway siding is a real advantage, and for many industries a necessity, and the railway company should be consulted as to what prospects there are of having one laid and the most suitable position for it. Where a siding is considered necessary, and the site adjoins the main line, it should be assumed that the railway company will only be able to consider putting in a siding on the up or down slow line. Further, it is not usual to put in a siding on an outside curve. It should be understood that the initial and maintenance costs will require to be borne by the firm who uses the siding.

Approach roads to the site should be sufficiently wide and reinforced to deal with the firm's road traffic and personnel. Sites which involve road traffic having to use low under-bridges, light over-bridges, and narrow roads should be avoided. Where these exist the prospective purchaser of a site may be informed of a project for developing the area under a town planning or similar scheme, thus overcoming these disadvantages. He must, however, treat such schemes with the greatest reserve because they have a bad habit of being shelved for years.

In spite of the advantages which are derived by many industries by direct access to a navigable river or canal, sites affording such access must always be accepted with some reservation. Whilst they are provided with one of the cheapest means of transport for coal and other commodities, they are usually comparatively expensive sites, and foundation costs are high. Moreover, where land on the banks of a river or canal has been used as a dump for refuse, it is a frequent source of vermin, which will be difficult to eradicate when the factory is in operation.

In the case of a site near the mouth of a river, painting costs will be high as a safeguard against corrosion, and there is the probability of dense fogs which render any outdoor activities extremely difficult, if not impossible.

Water Supply

Good water, and plenty of it, should be available at the site. In some areas, however, it will be necessary to install a water softening plant. Permission cannot always be obtained to take water from a river or canal for cooling purposes, but where it presents no difficulty the usual charge is so much per kilowatt generated.

The Fisheries Board must be considered when it is proposed to use river water, and in those instances where the water is to be returned to the river after process work it is not unlikely that the Board will require an efficient purification plant to be installed. Water companies are often faced with difficulties, and they will not be too anxious to negotiate if there is a likelihood of a still heavier demand being imposed upon their already overtaxed systems.

The pressure available should be ascertained, and if a booster pump is used in the supply mains it should be made clear whether or not the pump is kept running through the night. If the pressure is likely to fall at night, it is necessary to consider the advisability of installing a parachute tank, otherwise there may be disastrous results in the event of a fire breaking out.

There is, of course, always the alternative of considering the sinking of an artesian well, and the provision of a reservoir. Information with regard to other wells in the locality is usually obtainable and the quality and hardness of the water should be ascertained. This factor is highly important where chemical processes and breweries are concerned.

Water Supply Regulations

The following clauses are typical of those included in any agreement

drawn up by a water board and which are required to be signed by the consumer for a supply of water—

(1) The meter and appurtenances shall be fixed by the council at the expense of the consumer. Should the consumer discontinue the supply of water or the use of the meter, the council shall have the power to disconnect the communication pipe from their pipes, and the expenses of such removal and disconnection shall be borne by the consumer.

(2) The consumer shall provide immediately inside his premises a suitable site for the meter, and shall provide a suitable chamber for its protection. The meter shall be so placed as to be easily accessible for inspection, repair or renewal.

(3) No liability shall attach to the council in the event of any failure, deficiency, or lack or excess of pressure in the supply of water under this Agreement. The consumer shall provide a sufficient storage cistern or tank, if necessary, for the purpose of meeting his requirements.

(4) All hydraulic engines or other apparatus liable to cause shock or vibration to the meter or the supply pipe or fittings, shall be provided with air-vessels of design and dimensions approved by the council, and such air-vessels shall be maintained in working order to the satisfaction of the council, at the cost of the consumer.

Power Services

Electricity is invariably required in a modern factory and nowadays there is seldom any difficulty in obtaining a supply. If the supply company is privately owned, inquiries should be made from various sources to ascertain whether the service suffers from breakdowns.

A good supply of town gas at a suitable pressure is generally advisable and even though gas may not be deemed necessary it would be unwise not to take it into consideration. Gas companies are usually most helpful, and if they state they can supply in large quantities it should be verified that the anticipated demands can be fully met. The alternative is to install a gas generating plant.

The question of power services is more fully discussed in Chapter IV.

Drainage

The problem that may arise with the local water board may also arise with the local authority regarding the use of the sewers. These may already be overloaded, in which case it is unlikely that the drainage from an entire factory will be permitted to discharge into them. This may mean the installation of a sewage disposal plant at the expense of the factory owner. Sometimes, although the available drainage system is adequate, the local council will not give permission for certain trade wastes to be run into the sewers, as such may cause trouble at the sewage farm.

If the site is located on low-lying land, which of course often occurs at the mouth of a river, the sewage and storm water is disposed of by a pumping plant. Any equipment of this kind should provide for emergencies as, if it breaks down, which is quite possible during a particularly heavy storm, extensive damage may occur by the factory being flooded.

Purchasing Price

The prime cost of the site is a matter which must be settled by the directors. Intelligent purchasing is most important, and in order to avoid enhanced prices it may prove desirable for one or two adjacent plots to be bought in the names of private individuals.

In some instances a site has been acquired by a firm at a moderate cost with a view to future extensions of its factory. Within a few years, however, the value of this land has increased considerably due to the rapid development of a borough or some similar cause. The firm has then profited by disposing of this site and buying land elsewhere, thus obtaining a handsome surplus.

Personnel

The class of labour in the locality must be suitable for the industry. If not, comings and goings will be all too frequent, and this is extremely wasteful. It can indeed be said that continuity of service is essential for the successful working of any business. In localities where industries are numerous, the men are generally found to be more independent. Again, it is generally considered that good female labour is not so readily obtainable where the heavy industries are known to flourish.

If the factory is to be located in a suburban or rural area there must be proper consideration given to housing and transport facilities, otherwise the best type of employee will not be induced to seek the employment offered. As is well known, many of the largest firms have themselves successfully undertaken the establishment of the entire housing scheme and the setting up of townships. It should be borne in mind that modern town-planning schemes usually stipulate that certain zones shall have a limited population.

Almost invariably it will be worth while to consult the Ministry of Health and Ministry of Labour on a number of these points, and also to ascertain whether or not there are frequent labour troubles in the district.

Climate

The meteorological record of the prospective site is worth studying. It is natural for everyone to be more cheerful if the locality gets its fair share of sunshine. Extremes are not desirable. Hot weather is not conducive to sustained effort, whilst an extensive winter period involves extra expense in the provision of heating facilities. Fogs will inevitably result in a higher proportion of late staff and difficulties with transport and outdoor work generally, and heavy rains will necessitate special arrangements for the protection of material.

The nature of the work carried out at neighbouring factories should be considered, because fumes may be emitted which are injurious to the product of the proposed new factory.

Existing Factory Sites

Although it has so far been assumed that a factory site is being sought in an area upon which no buildings have hitherto been erected, it is as well to remember that in the British Isles there is a pronounced tendency to purchase a site which already includes factory buildings which, with or without structural alterations, will be suitable for the type of industry proposed. This applies particularly to the smaller factories, the reason advanced for this policy being that the capital cost in laying out the factory is

materially reduced—a factor which is considered by many to be more important than the minor though permanent inconveniences which may arise by using buildings originally erected for other purposes.

Even though an existing factory site is contemplated, the questionnaire given on page 18 should be answered. The only difference is that in this instance the task of solving certain problems will not arise, the mere fact of buildings having already been erected automatically settling a number of preliminary points, e.g. the foundations necessary, or the disposal of sewage. On the other hand, such items as the local rates, or the availability of suitable labour, still arise, and require most careful consideration. Who knows but that it may have been for one or more of these reasons that the original factory had to close down!

In addition to the questionnaire it is equally important that the block plan showing the ideal layout should be prepared and followed as far as the existing buildings will allow. Careful reference to the ideal layout will avoid an unsuitable site being selected.

CHAPTER III

LAYOUT OF FACTORIES

THE detail planning of a factory is a complex problem which calls for an intimate knowledge of the particular industry concerned, combined with considerable administrative ability. Before considering the matter further, however, it will be advisable to classify industry.

Classification of Industry

Industry may be broadly classified under four major headings as follows—

1. *Type of Industry.* There are two main divisions, one of these being called "continuous" and the other "assembly." With "continuous" industries the material is received at one point and successive operations convert it into the finished product. "Continuous" industries are of two classes, (*a*) the scientific, in which different ingredients are worked into the finished product, e.g. paint and paper, and (*b*) analytical, in which different substances are separated from the original material and the finished product left, e.g. iron smelting and oil refining.

With "assembly" industries various components are made first and then they are put together to form a whole unit. These industries also fall into two classes, (*a*) similar components and operations, e.g. clothing and cabinet-making, and (*b*) dissimilar components and operations, e.g. locomotives and ship-building.

2. *Type of Product.* The product may be heavy or light, large or small, solid or liquid. For example, the building of aeroplanes and the manufacture of television sets are both assembly industries, yet they require entirely different layouts; and if the product is a liquid and is capable of flowing or being pumped, the problems regarding the layout are necessarily quite different from those which arise when a product must be man-handled.

3. *Type of Operation.* Every industry presents difficulties of its own. For instance, with powder manufacture there is a special fire risk to be guarded against; with a chemical process there is the risk of the process worker being gassed; with instrument making it is necessary for machine tools and other equipment to have a high degree of accuracy.

4. *Type of Employee.* The requirements of the product may involve a large proportion of skilled labour, e.g. diesel engines, or it may be largely semi-skilled labour, e.g. the chemical industries. Alternatively, it may be mostly female labour which is required, e.g. the textile trade.

Floor Areas

When considering the actual layout there can be no problem in the initial stages more important than that of determining the floor space. For machine tools and other fixed

equipment the area required will be the total of the areas covered by each machine and its foundations, due allowance being made for the movement of the operator, the floor space for the completed work and work in progress, and gangway areas. The gangways should always be ample, allowing easy access for an electric or petrol motor truck, if desired. Where machines require little attention after having once been set up, some minor convenience may be sacrificed in order to save valuable floor space. In the case of comparatively small machines the distance between each machine may be determined by the distance required by each operator and not by the size of the machine. Wherever practicable, working gangways should not be used for transport, otherwise the machine operators will have a feeling of restraint when moving about their machines. It is surprising to find that even with identical products the amount of space which is required for material and work in progress varies considerably with different firms, due to differences in administration and systems of manufacture. Apart from this, there are three classes of work to be considered so far as space requirements are concerned: (*a*) small details which may be carried in quantities in trays or boxes, (*b*) details which require separate handling but can be man-handled, and (*c*) details which cannot be man-handled and therefore require crane power. With the first class large quantities can usually be conveniently accommodated on stands or benches at the side of the machine. With press or similar work unusually large quantities will be involved, and provision must be made to avoid a serious "banking up" in the event of an interruption in the flow of work at some other point in a group of machines. The best plan is to provide island areas at suitable places amongst the machines. With the second class the work will cover a very wide range. Here, however, the golden rule to be applied is that "the shop floor is not a store," and, taking into account the rate of output, provision should only be made at the machine to accommodate material required for twenty-four hours or so. There are a few exceptional cases as, for instance, in woodworking plant where there is a vast output and a large quantity of material in progress necessitating ample storage space to ensure an even flow of work and transport facilities. With the third class of work there must be ample crane power and sufficient labouring staff available, otherwise valuable time will be lost in holding up expensive machines and plant.

The bay formed by a shop overhead travelling crane often lends itself to a centre aisle being formed, and the use of this for temporary storage may be fully justified. At the same time covered floor space is costly, and it is seldom justifiable for large masses of work to be left in the shop at various stages of manufacture.

Design of Buildings

The general function of factory buildings is to provide cover and safe accommodation for employees, plant, machinery, and equipment, which will

ensure the most efficient protection and will conform to all the requirements of the Factories Act, local bylaws, and insurance company regulations. The type of building to be erected for any particular department will depend on several factors—(*a*) the area available for the particular process, (*b*) the aspect and environment of the building site, (*c*) the volume and nature both of the materials to be used and of the finished product, (*d*) the manufacturing processes involved, (*e*) the type and quantity of machinery and equipment to be installed.

Let us compare and contrast the single-story with the multi-story building.

Single-story	Multi-story
Cheaper foundations and walls.	Economy of land if costly to purchase.
Extensive natural lighting.	Efficiency of heating and ventilation systems giving greater comfort to employees.
Facility of supervision.	Saving in transport provided that a good lift service is installed.
Freedom from vibration.	
Permits of satisfactory arrangement of all sections.	

Generally, single-story buildings will find most favour, particularly with the heavy industries, although there are many cases where a factory can with advantage comprise both single and multi-story buildings. If all departments are under one roof freedom of action is somewhat restricted, and it is impossible to isolate obnoxious fumes and processes, efficiency thereby being reduced.

Foundations

The foundations must be adequate for whatever type of building is under consideration. If the ground is damp, the foundations may be supported on piles of wood or concrete. Artificial foundations to make up deficiencies of the ground in bearing power are usually of concrete.

Building Construction

The first consideration is the comfort of the employee, otherwise economic production will not be obtained. With that in mind the next consideration is simplicity and economy of design combined with strength and ability to withstand wear. It is recommended that brick or masonry, when used alone, should only be used for single-story buildings with truss roofs. The materials are cheap but the labour cost of erection is great. Concrete blocks are similar to brickwork and masonry except for the material used. The blocks are often made by a machine on the site, "hard" blocks being made with cement combined with crushed stone, brick or gravel, whilst "soft" blocks are made from cement combined with "breeze," i.e. cinders. There are many proprietary brands on the market. Usually the hollow type is cheapest and is less heat conducting. They are often used for dividing walls and small buildings. Reinforced concrete is frequently used in the modern factory building, steel beams taking the tensile stresses. It is speedy to erect, is highly fire resisting, low in maintenance costs, and allows of easy vertical extension, a flat roof being usual. The floors are carried by beams mounted on columns which are supported by the foundations. Built-in power cables are encased in impregnable insulation to prevent

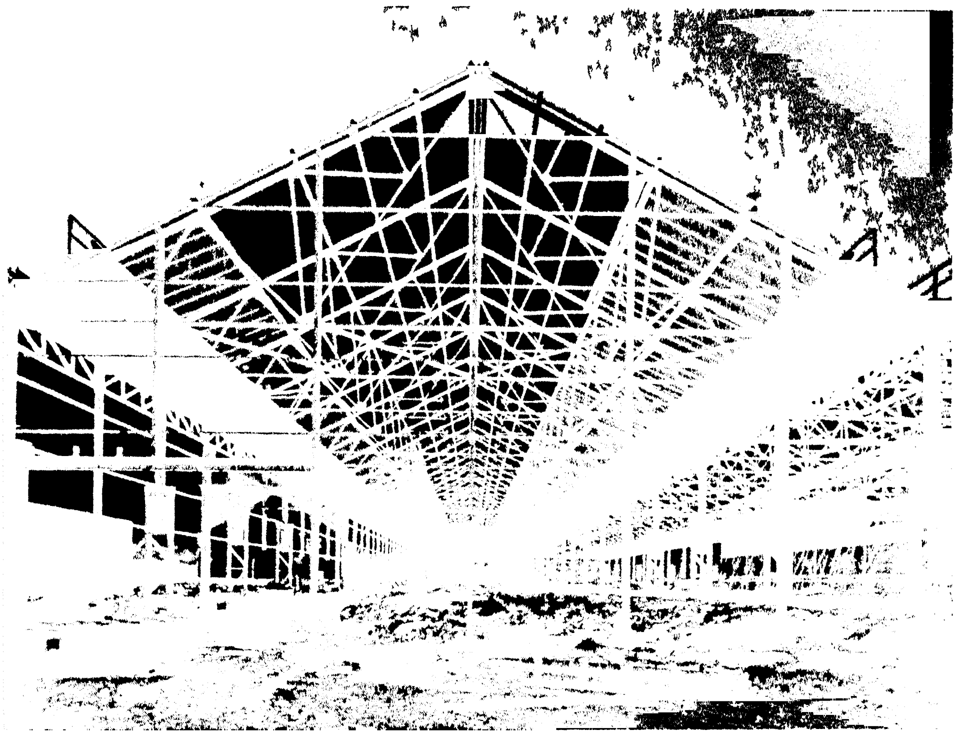


FIG. 9. ONE BAY OF A BUILDING COMPRISING TWO BAYS EACH 480 FT. LONG, 75 FT. SPAN AND 25 FT. HIGH TO EAVES.

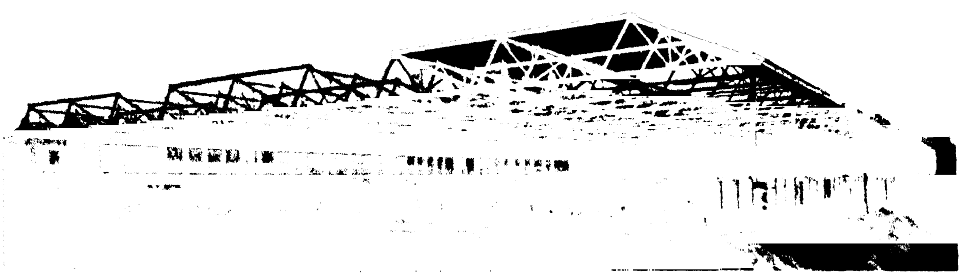


FIG. 10. BUILDING OF STEEL CONSTRUCTION EMBODYING WARREN GIRDER NORTH LIGHT ROOF.

leakage to the soil. Good materials and careful workmanship are essential.

Steel Frame Construction

A steel frame construction has everything to commend it, in view of its low cost and rapid erection. The vertical steel columns are connected by horizontal girders and beams and are surmounted by the roof trusses. With steel construction the walls are only required as casings and may be of brick, plaster, corrugated iron, or asbestos sheeting. The accompanying photographs, Figs. 9 to 18, clearly illustrate the construction of different types of modern steel buildings. In all cases it should be remembered that a lofty building permits of a more crowded floor space than one with a lower roof.

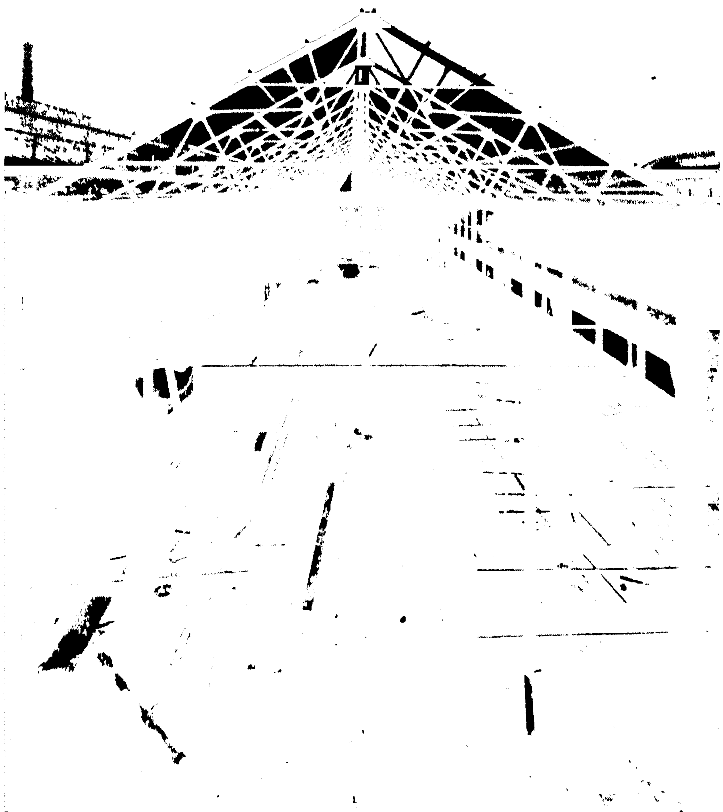


FIG. 11. EXTENSION TO A MACHINE SHOP 300 FT. LONG, 50 FT. SPAN, 30 FT. TO EAVES, COMPLETE WITH CRANE RUNWAY

Timber is suitable for small light structures where there is no fire risk. The cost is low and a long life results if the timber is well seasoned and kept well painted. Deal and Oregon pine

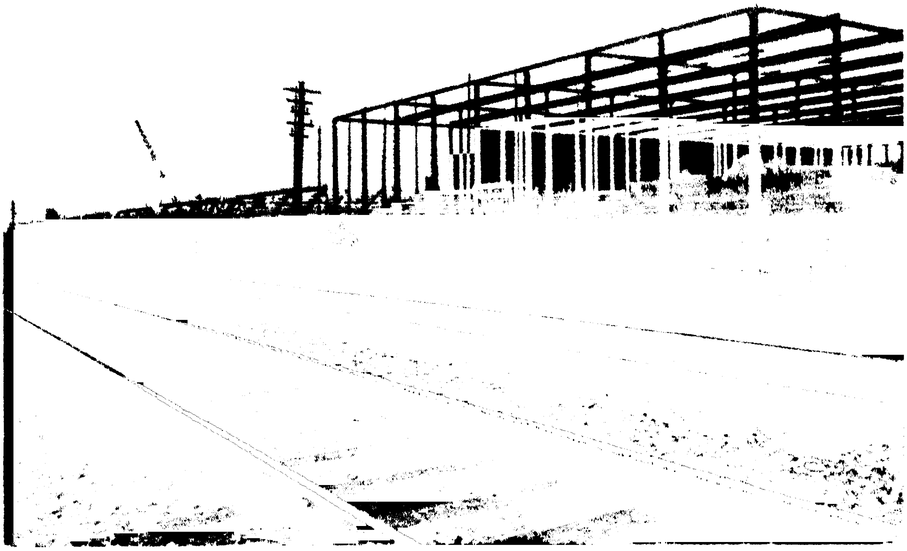


FIG 12 BUILDING WITH A WARREN GIRDER NORTH LIGHT ROOF AND A TWO STORY ANNEXE ADJOINING.

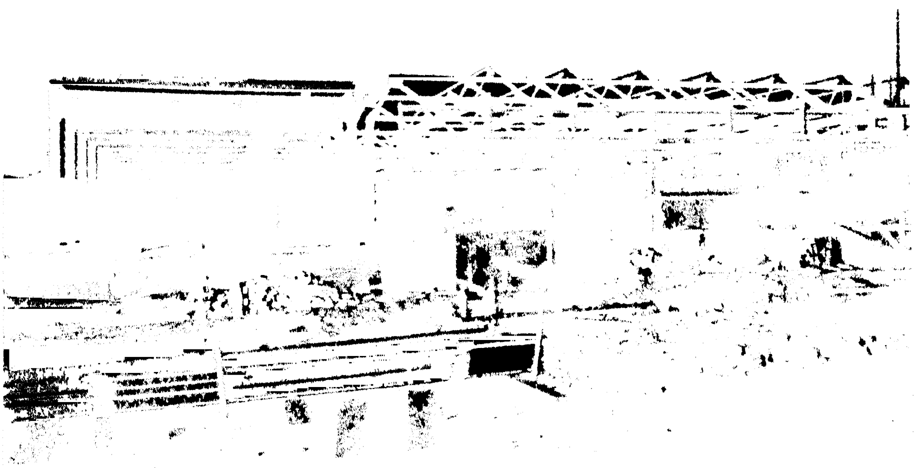


FIG 13 APPROVED TYPES OF STEEL CONSTRUCTION

are best for dry situations, and oak and ash when exposed to the weather.

Roofing

There are four distinct types of roof used in single-story buildings, i.e. saw tooth or north light roof, span roof, flat roof, and the type of roof suitable for accommodating cranes. Examples of each are shown in the accompanying photographs. The first-mentioned has the light facing the most northerly aspect available and is often favoured. The modern truss girder permits of columns far enough apart to allow the flooring to be reasonably free from obstruction. Span roofs of steel construction are very good. They are suitable for carrying light suspended loads, such as pipes and transmission gearing. A noteworthy exception to steel construction is the lattice girder roof which has gained considerable popularity. Figs. 14 and 15 show this particular type of roof. Briefly, its advantages are—

(1) It can be constructed in any span desired up to 120 ft.

(2) It combines light weight with strength and rigidity.

(3) When covered in bituminous roofing it forms an extremely well-insulated roof which does not give rise to condensation troubles.

(4) Roof lights can be embodied to any extent desired.

(5) The trusses can be made to carry counter-shafting or other loads where specified.

(6) The roof can be fabricated on the site to any shape of building and can be erected speedily.

(7) Gutters can be formed in the roof materials and can be made to discharge in long stretches, thus minimizing the number of downpipes.

With flat roofs, excessive strength to withstand snow, and a gradient of 1 in 40 for drainage purposes are necessary. This type of roof cannot be recommended if a single-story building is contemplated with a width exceeding 60 ft. If, however, it is anticipated that such a roof may some day carry another floor, it should be of robust construction, and as in this case it will not be given the small gradient mentioned, it must be made especially water-tight. Tiles and slates are frequently replaced by lighter materials. What is essential is that all coverings must be durable, impermeable, and acid resisting.

Multi-story Buildings

The roof construction of a multi-story building may be the same as that of a single-story building, but with the extensive use of reinforced concrete a flat roof is generally preferred. One advantage is that the smaller air volume will tend to reduce heating losses.

The practice of incorporating galleries in single-story buildings does not commend itself, as poor illumination, draughts, faulty ventilation, and noise are all prevalent in such cases. Lofty crane runways carrying large-capacity cranes may with advantage have lower runways beneath them with auxiliary cranes.

In the case of multi-story buildings the width of building should not exceed the height from ceiling to floor, which will normally limit the width to

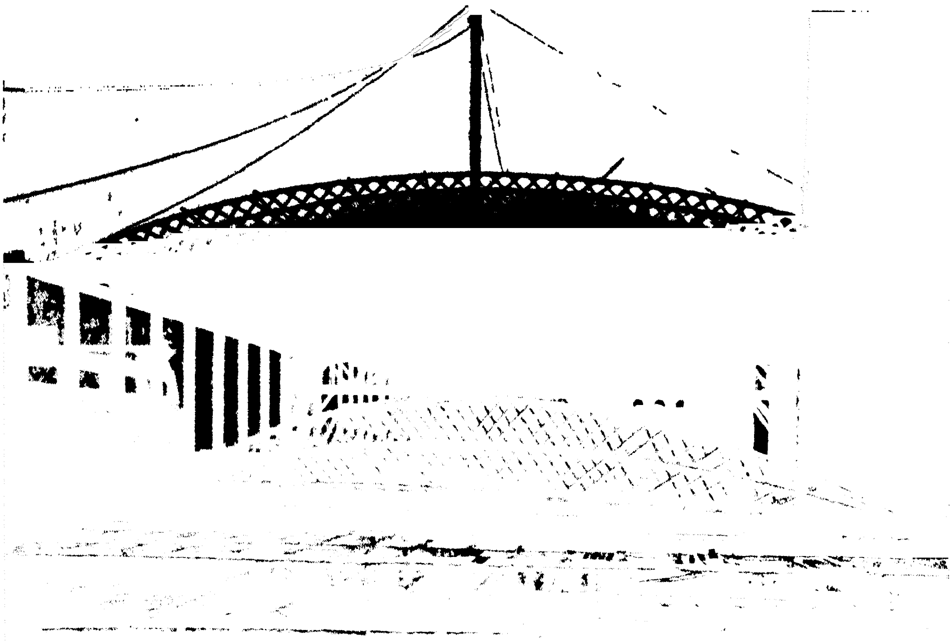


FIG. 14. LATTICE GIRDER ROOF IN COURSE OF ERECTION: SPAN 120 FT.

FIG. 15. COMPLETED BUILDING AT THE MORRIS MOTOR WORKS EMBODYING LATTICE GIRDER TYPE OF ROOF

60 ft. or 70 ft. If these dimensions are exceeded, it is impossible to get satisfactory natural illumination. Again, to ensure daylight for a ground floor, the distance between parallel buildings must not be less than the height of the buildings. The danger to be guarded against with multi-story buildings is the weakening which may be caused by the percolation of liquid softening the concrete or steel reinforcement, or corroding the structural beams.

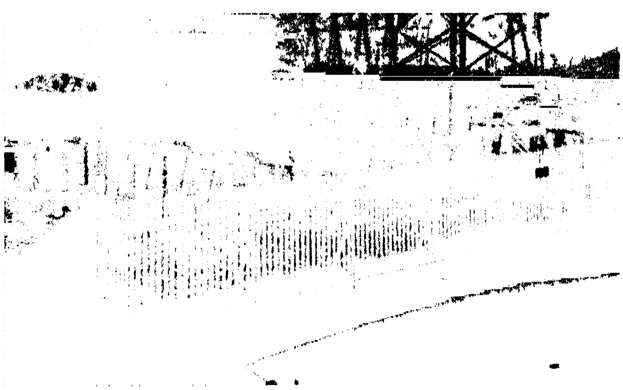


FIG. 16. UNCLIMBABLE STEEL FENCING

Flooring

The suitability and durability of flooring materials depend on two factors: (*a*) the weight to be carried, and (*b*) the "service" required having regard to the shop process. In some industries the nature of the processes carried on gives rise to the deterioration of flooring from chemical causes, whilst in others the major problem is that of obtaining suitable resistance to wear and abrasion. In addition to resistance to chemical or mechanical attack, comfort characteristics such as warmth, quietness, and non-slipping properties are also of importance. For general use, say, in a machine, fitting, or erecting shop, there is no doubt that amongst the best types of floor is one of concrete over which is placed a layer of creosoted wood blocks placed on end. For heavy work a granolithic foundation comprising a mixture of granite chippings and cement is preferable. To-day there are numerous patent floorings on the market. Suspended floors will require to be of fire-proof construction.

A systematic inspection of the buildings and the prompt execution of repairs, coupled with periodic painting, will keep depreciation losses at a minimum.

Where it is necessary to provide a boundary it may be considered too expensive to erect a brick or concrete wall. In such circumstances an unclimbable steel fencing of the type shown in Fig. 16 will provide an excellent substitute.

Detailed Layout

Assuming that the size, shape, and height of each building has been tentatively settled, the next stage is to consider the detailed layout of the proposed available space. The following points will need to be considered—

1. *Air Space.* The number of employees under each roof must be estimated to ensure that ample air space will be available and that it will not be less than the 400 cub. ft. per head stipulated by the Factories Act. Any height above 14 ft. is not to be

included in the calculation. For a new building it is recommended that a volume of 500 cub. ft. per person be allowed, based on a maximum height of 12 ft. instead of 14 ft.

2. *Complete Balancing of Departments.* Apart from making provision for possible expansion, it is of the utmost importance that not only each department, but each individual operation, shall be able to absorb the work from previous departments and operations, and transmit it to subsequent ones in such a manner that all the available equipment shall be fully occupied. After all, it is useless for the fitting shop staff to be calling for more work if the machine shop is unable to keep them supplied!

3. *Planning of Production Areas.* As with the general planning referred to in the previous chapter, small paper templets to represent individual machines and fixed plant should invariably be used as an aid to the systematic planning and layout of each department.

4. *Direct Line Layout.* There should be a minimum of backward movement for both material and operators. In "assembly" industries this arrangement may require slight modification owing to the necessity for a machine having to perform operations which are not consecutive, either because there is not enough work for two machines, or because an operator who is not a machinist has to perform more than one operation, and it may be cheaper to move the material rather than the individual. So far as the latter is concerned, the ideal is to train men for specific operations and have a special area allotted to them, and arrange for the material, if it is reasonably movable, to be passed to them—not the men to the material.

5. *Transport.* Good roads are essential. The distance between the different work centres must be as short and direct as is convenient, more particularly if the product is heavy or unwieldy. Gangways must be kept clear, and angles between bays must permit of easy curves for internal transport.

6. *Service Areas.* Tool stores, material sub-stores, and the like must be arranged at convenient centres, but must not impede production.

Departmental Requirements

In a book which attempts to cover the whole field of factory management it is not possible, even assuming it was feasible, to cover in detail the layout of every department which occurs in an engineering factory. It is, however, desirable that some general reference should be made to each of the more usual operations and departments.

Accessories. It is recommended that the majority be purchased outside, this procedure generally being the more economical.

Castings. The type of furnace decided upon will depend chiefly on the nature of the product. If the requirements are only a few tons per week, it may be considered more economical to prepare the patterns and to purchase the castings from an outside source. Where large cast-iron and steel castings are involved, careful scrutiny of the drawings should be made to see whether it is not possible to suggest

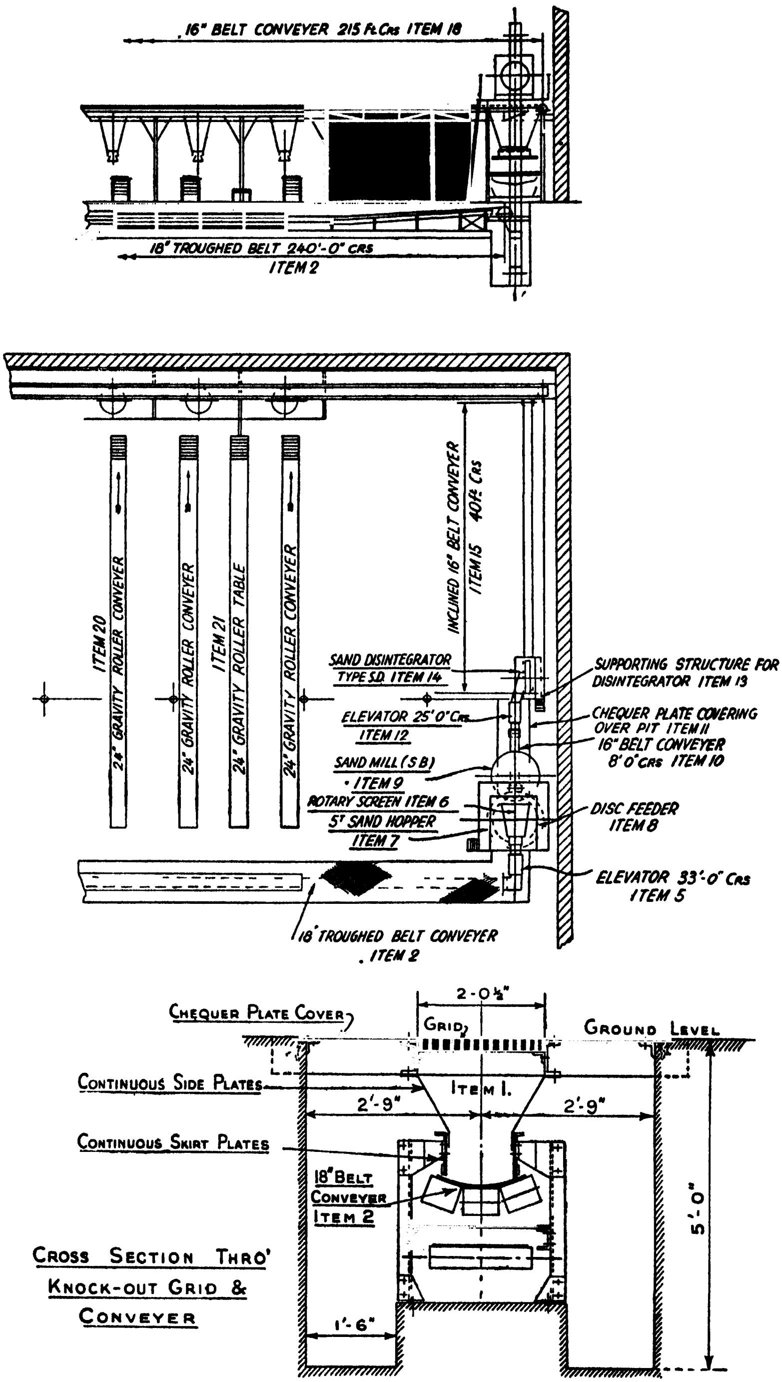


Fig. 17. Suggested Layout for Mechanized Foundry

a re-design and substitute a fabricated unit. Where this is done patterns and core-boxes will be dispensed with, and the fabricated unit will frequently be cheaper and stronger. For smaller castings every effort should be directed towards machine moulding.

There will be four distinct sections in every foundry—

(*a*) Core-making. Core ovens may be heated by coke, gas, or electricity.

(*b*) Floor moulding.

(*c*) Machine and plate moulding.

(*d*) Fettling. Pneumatic chisels.

A suggested layout for a mechanized non-ferrous foundry is shown in Fig. 17.

Die Casting. This operation has much in its favour but should only be considered when large quantities are involved, otherwise it is uneconomical.

Erecting. In order to lessen fatigue and reduce accidents, it is desirable that men should work at ground level wherever practicable thus eliminating staging and trestles. Wherever it is a practicable proposition pits should be provided which will either (*a*) accommodate the work, or (*b*) accommodate the men. Fig. 18 clearly illustrates the latter arrangement.

Fibre and Rubber Parts. Fibre rod bushes, etc., of various diameters may be machined in the factory. They are a specialist branch of industry and, if the details are comparatively few, outside purchase is best.

Finishing. A certain amount of isolation is desirable in the case of the paint shop, although it is intimately concerned with transport. Spray painting equipment and stencilling should be introduced wherever practicable.

Fitting and Assembling. This department is the "consummation of machining" and requires the closest co-operation with the machine shop. A saving of space is often achieved by "staggering" the benches (see Pattern-making). The accompanying photograph, Fig. 19, shows a well-arranged line of fixtures for locomotive connecting rods. The fixtures operate on ball bearings and permit easy handling of the rods. Similarly, Fig. 20 is a very good layout of an assembly shop for electric motors. In this case it will be noticed that provision is made for the operators to sit down—a particularly desirable feature wherever it can be arranged.

Forging and Stamping. Wise buying of forging and "upsetting" machines in conjunction with oxy-acetylene and coal gas cutting machines will eliminate much costly smiths' work carried out under the steam hammer.

Hot Pressing. This operation necessitates a fairly high capital expenditure in the purchase of equipment, but assuming mass production is involved the working costs are particularly low and subsequent machining is practically eliminated. Success in this department largely depends on the employment of one or more highly skilled and efficient die sinkers.

Machining. In most factories the machine shop is the "hub of the universe," as it unconsciously sets the pace for all other departments both manufacturing and assembling. It offers the greatest scope for economical production. According to the product involved a decision will require to be made as to whether machines of a

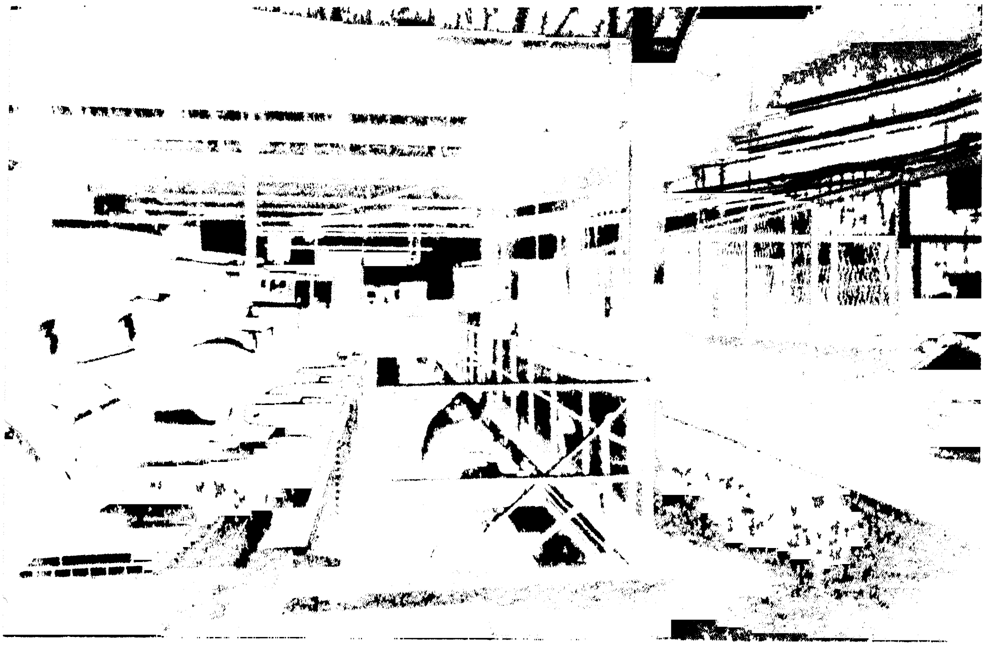


FIG 18. MOTOR VEHICLE INSPECTION PITS

FIG. 19. LINE OF FIXTURES FOR ASSEMBLY OF LOCOMOTIVE CONNECTING RODS

FIG 20 ASSEMBLY SHOP LAYOUT FOR ELECTRIC MOTORS

FIG 21 MACHINE SHOP LAYOUT IN TYPE FACTORY

similar type shall be grouped together or whether they shall be arranged regardless of type, but to bring together a complete sequence of operations which are needed for a component which is repeatedly being manufactured, and thus ensure that articles progress in one direction only. Automatic machines should be grouped together, whilst the marking-out tables and tool stores should be located as

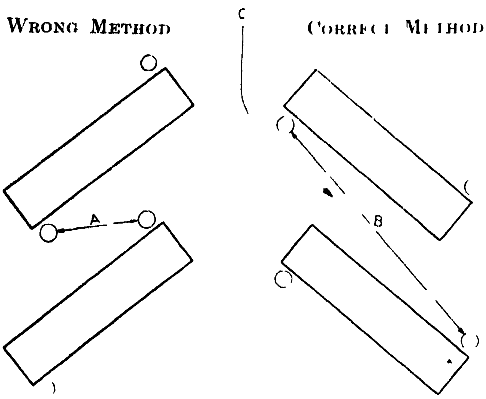


FIG 22 STAGGERING OF BENCHES IN A MANNER WHICH GIVES MAXIMUM FREEDOM TO BENCH HANDS

Note Incoming material should be admitted in the direction of "C" in order to ensure a wide angle of entry

centrally as possible. Fig. 21 shows a splendid layout of a machine shop forming part of a tyre factory.

Millwrights. If the factory is a large one, a separate millwrights' shop, for the purpose of installing any new equipment, as well as maintaining all machines, plant and services, will be fully justified. The equipment should include a limited number of general purpose machines.

Packing and Dispatch. These should be adjacent to the paint shop and assembly department and within easy access of the works' exit.

Pattern-making. The pattern shop is a comparatively expensive department, as a large proportion of costly hand work is involved and it is scarcely ever possible to predetermine basic times or piecework prices. Where benches are "staggered" in order to give a wider central gangway, it should be observed that there is a wrong way (A) and a right way (B) of "staggering," as shown in Fig. 22. Machines should in all cases be located at one end of the shop. The pattern-maker himself is among the most highly skilled of craftsmen and in addition must be thoroughly conversant with foundry requirements. For some unaccountable reason the pattern-maker, and his close ally, the joiner, are expected to provide their own hand tools.

The exploitation of universal wood pattern-making machines is well worthy of consideration. Patterns should be of metal if the quantity of castings justifies it, such a pattern first being prepared from a wooden master pattern. Metal plate patterns should be adopted wherever practicable to enable the work to be prepared on a moulding machine which permits of semi-skilled labour in the foundry.

Plate and Sheet Metal Work. A large proportion of this is hand work, and to cheapen manufacture mechanical aids and jigs should be introduced wherever practicable. The bulk of supplies comes from the raw material stores, and for this reason it will be advisable to locate this department and the material stores adjacent to each other.

Raw Material Store. The first consideration is that the raw material store should have easy access to the forge. Foundry supplies are usually kept separate. The accompanying chart, Fig. 23, will give a clear impression of the alternative routes followed by raw materials.

First, there are what are known as the "ferrous" (iron base) metals. These consist of iron ore, pig iron, and selected scrap. Iron ore is used only in the manufacture of steel ingots. Pig iron may be purchased in various parts of the country, each different brand being obtained for a specific purpose.

Brasses and bronzes are known as "non-ferrous" metals, and the raw material consists almost entirely of pure metals, such as copper, zinc, tin, lead, aluminium, and selected recovered scrap material.

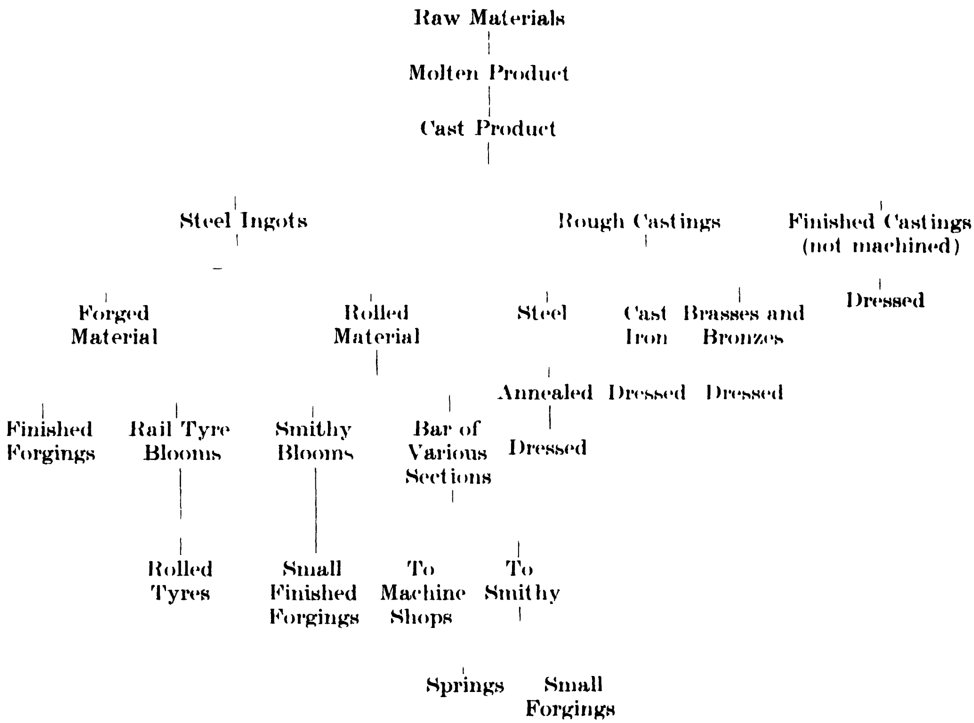


FIG. 23. CHART SHOWING DIFFERENT DIRECTIONS TAKEN BY RAW MATERIALS

The materials having been selected and weighed in the correct proportions to give the desired properties, which are also related to the chemical analysis, they are then placed in a suitable furnace and melted down. Reference to the chart will show that the products of the furnaces can be separated into two distinct groups—ingot steel and castings. In both cases test pieces are essential to ensure that

the material is in the correct structural state and free from inclusions which would impair its usefulness.

Incidentally both the forge and the foundry are classed as "manufacturing" departments and their products referred to as "rough" material.

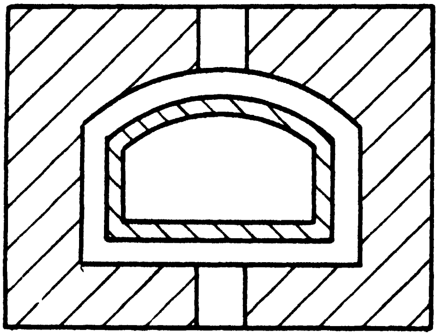


FIG 24. CROSS-SECTION OF MUFFLE FURNACE

Annealing, Normalizing, Hardening, Heat-treatment, Case-hardening, and Reheating. The heat-treatment of steel comprises various combinations of heating and cooling with a view to producing or rendering permanent desired physical characteristics.

Metallurgical progress has resulted in the production of a considerable range of special qualities of steel, each of which is especially suitable for individual purposes. Heat-treatment specifications become increasingly exacting and many of them are impossible to fulfil except in furnaces which are capable of working to within a few degrees of specified temperature and which are also capable of applying heat uniformly throughout the charge. Especially is this true of alloy steels and steels of higher carbon content. It is, therefore, essential that the furnaces employed for the thermal processes should be carefully designed, constructed, and operated in order to ensure the gradual, uniform, and efficient heating of the different steels under controllable conditions.

To determine the best furnace for any particular class of work many factors have to be considered, such as the best fuel to use, output required, accuracy of temperature control, freedom from oxidation or decarburization, and whether the furnace is required for intermittent or continuous work.

The terms "oven" and "muffle" are sometimes used indiscriminately, and to avoid confusion diagrammatic sections are shown to illustrate the difference.

Fig. 24 shows a cross-section of a muffle furnace in which the work is completely protected from the products of combustion. Such furnaces are largely used for ceramic work and for the heat-treatment of metals where

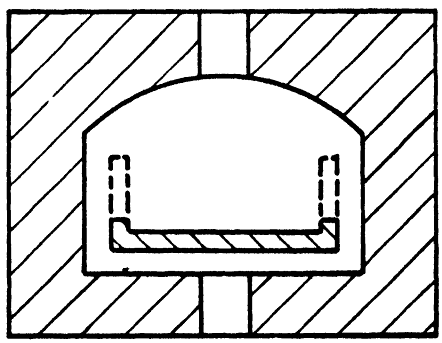


FIG. 25. SIMPLEST FORM OF OVEN FURNACE

the introduction of a controlled atmosphere is essential to protect the work. Fireclay muffles are in common use but carborundum and heat-resisting alloys are also used. Fig. 25 shows the simplest type of oven furnace

where the products of combustion pass through the working chambers. These are sometimes referred to as semi-muffle furnaces when high guard tiles are provided at the sides to protect the work from the direct heat of the flame. Oven furnaces are mostly employed on carburizing, annealing of

FIG. 26. BATTERY OF ELECTRIC FURNACES

steel and other metals, and general heat-treatment. Electric furnaces have an extensive application and Fig. 26 gives a good impression of the layout required for a battery of such furnaces.

Receiving Department. It is necessary that this should have direct communication with the outside road, preferably other than the main works' entrance, and also with the raw material store.

Tool Shop. There is everything to be said in favour of a separate shop. It eliminates any suggestion that one shop or another receives preferential treatment. Fig. 27 shows a row of tool room lathes, and Fig. 28 shows another view with relieving lathes in the foreground.

Welding. The general policy of isolating each operator in a cubicle, wherever practicable, will commend itself to most engineers. Such an arrangement minimizes accidents.

General Offices. The administrative and general offices should be located nearest to the main works' entrance. Where more than one floor is decided upon, the ground floor should include the inquiry office, the personnel

FIG 27 ROW OF TOOL ROOM LATHES

FIG 28 TOOL ROOM LATHES WITH RELIEVING LATHES IN THE FOREGROUND

department, and all other offices directly associated with the works. The different sections of staff which come under the jurisdiction of the production manager or equivalent officer should preferably be located in one large ground floor office.

Office work requires to be organized on progressive lines in much the same way as is done in the workshops. This is essential if unnecessary handling of paper is to be eliminated. In large offices the amount of time spent sorting and handling paper is generally tremendous, but this can be reasonably reduced by using modern types of accounting machinery. Where practicable the offices should be laid out so that the documents are received from the works at one end of the building and worked through to the accountants' offices where they are dealt with finally. It is a good plan to have the wages documents received at one end of the building and the material documents at the other, so that the two do not get mixed. A centrally situated machine bureau is obviously an advantage in this case, as the documents will move forward in sequence to the costs or accounts office and in their course will pass through the machine room. Much time can be saved by a properly laid out office, just as production is expedited by the correct outlay of machinery and plant in the works. Fig. 74, Chapter VI, shows a particularly good office layout.

Office Layout

So far we have only been able to speak in general terms of the layout required for those departments which deal with the more common classes of work; unfortunately specialized requirements cannot even be mentioned. But when it comes to the layout of offices much more detailed information is possible because of their general application to every industry.

In the first place it is important that associated sections should be located as near as possible to each other, and that those having contact with the public should be located on the ground floor whenever practicable. The floor area should never be greater than is commensurate with the number of occupants, the construction of larger offices entailing unnecessary expense initially, as well as subsequently for their upkeep. Cubicles with a floor space of 100 sq. ft. are recommended in preference to private offices, the partitions facing general offices being fitted with clear glass from a height of 3 ft. upwards. External and internal angles should be rounded, and all junctions should have cove to eliminate surfaces where dust can lodge. Generally speaking doors should open into the room, this arrangement minimizing draughts. Window space should be as generous as possible, particularly in the case of drawing offices. Window-sills should be placed between 30 in. and 36 in. from the floor. Where separate typewriting and other machine bureaux are provided, reduction in the noise can be obtained by spraying asbestos or similar material on the walls.

Office Furniture

The name of every office should be shown on an indicator board. Single

desks should be provided (except to facilitate sectional work), a satisfactory size being 4 ft. 6 in. × 2 ft. 6 in. × 2 ft. 6 in. high. The right-hand pedestal should have three drawers, the top one having a lock. The left-hand pedestal should take the form of a cupboard with one shelf. For typists a steel table 4 ft. × 2 ft. × 2 ft. 3 in. high with closed sides and back is greatly favoured. One pedestal of three drawers arranged vertically on the left-hand side is sufficient in this case. All desks should be at right angles to the windows and the latter should preferably be to the left of the staff when seated, as in Fig. 29. Chairs for general use should have adjustable seats upholstered in moquette and measuring 14 in. from back to front. For typists the backs should be well padded and measure 12 in. in width. Domes of silence should be fitted to all chairs. A standard type of steel cupboard with adjustable shelves is strongly recommended. These should approximate to 7 ft. × 3 ft. and vary in depth from 10 in. to 15 in. according to requirements.

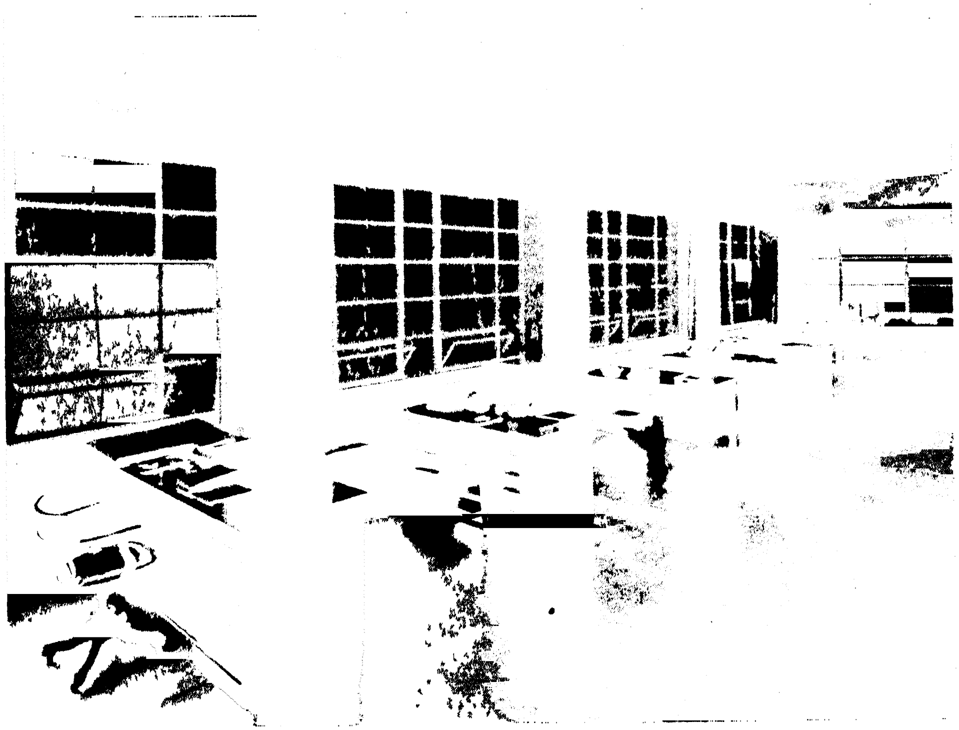


FIG. 29. CORRECT OFFICE LAYOUT WITH WINDOWS TO THE LEFT OF STAFF WHEN SEATED

Fire-fighting Equipment

It will be appropriate to conclude this chapter with the arrangements necessary to combat an outbreak of fire.

It need hardly be stressed that fire hazards in industrial organizations constitute a very important and destructive menace to plant, property, and stores, as well as to human lives, and every conceivable fire risk on the premises should be efficiently covered by the right type of fire-fighting equipment.

Light fire pumps or trailer-type fire engines, as well as power-driven fire pumps, may be considered to be among the most valuable forms of major fire equipment for large industrial premises. To be successful in fire fighting it must be distinctly understood that it is no use trying to work at a distance. Fire is extinguished either by exclusion of air or by lowering the temperature below that of ignition. With the former method the object is attained by smothering the burning substance or, in some cases, beating out the flames; with the latter, generally by the application of water. Working at a distance should only be done when the heat or danger of falling walls, roofs or floors prevents the firemen getting closer.

Fire fighting in its general sense cannot be applied to specialized industries where highly inflammable liquids and substances are manufactured or stored. Whilst water is the best known and most extensively used fire extinguishing agent, it is only suitable for application to freely burning materials such as wood, cloth, paper and similar substances. Its use is extremely dangerous on outbreaks involving materials of a highly inflammable nature, such as calcium carbide, metallic sodium, metallic potassium, and metallic calcium. Sand and earth are extremely valuable mediums for extinguishing oil or spirit fires and, if necessary, for forming a bank to prevent flow. It is, therefore, essential that the officer responsible for fire safety should be fully acquainted with the various methods of fire extinction.

Works Fire Brigade

In every factory a works fire brigade should function. It should be under the command of a captain who must satisfy himself that the appliances are distributed in the most advantageous positions throughout each building, and that they are maintained in good working condition. It is necessary that a diagram should be prepared indicating the position of all hydrants, stop valves, drain cocks, hose boxes, fire buckets and fire extinguishers, this diagram being exhibited in a prominent place. The fire brigade captain should also be responsible for the training of selected employees in the use of each type of appliance. Periodical fire drills, say once every calendar month, should be organized to keep the brigade in practice and to ensure that the entire personnel of the organization understand their movements in the event of an outbreak of fire. As far as possible all drills should be carried out during ordinary working hours. These rehearsals also ensure that the various appliances can be depended upon in an emergency. The captain of the brigade should keep a fire occurrence book, recording therein all changes of staff, dates of drills, dates and particulars of fires, appliances received or sent away for

repairs, etc., and all other relevant matters. Electric alarms are preferable to any other type, and in all cases should be tested frequently at stated times, and the tests recorded.

Fire Precautions

The following tabulated information shows some causes of outbreak of fire and the precautions recommended to minimize such outbreaks—

Cause	Example	Precautions
Direct ignition with flaming or glowing material, sometimes causing explosion.	Spark coming into contact with inflammable material, petrol vapour and gases in confined places.	Naked lights, flames, and burners used in manufacturing processes should be suitably shielded. Smoking and the use of matches in the vicinity of freely burning materials or highly inflammable liquids, gases, and substances should be strictly forbidden.
Prolonged heat, even though faint.	Stove pipe near to or resting upon unprotected woodwork.	Constructional defects should be remedied particularly in boilers, fires, and flues, where it may be possible for heat or sparks to come into contact with woodwork.
Spontaneous combustion.	Damp hay, straw, manure, etc., also cleaning cloths and waste left for comparatively long periods.	The immediate disposal of oily rags, paper, rubbish, and waste should be ensured. If temporary storage is necessary only metal containers should be used.
Electrical causes.	Short circuits, flashes of lightning, etc.	All electrical apparatus, fittings, switches, and leads should be insulated efficiently.
Chemical reaction.	Lime and water, acids in contact with other material through leaking vessels, etc.	Periodical inspection should be made of plant.
Focused rays of the sun.	Sun's rays pouring through unprotected roof lights, etc., or reflected from bottles, pieces of glass, etc.	Roofs to be darkened and windows shaded as considered necessary during the summer period.
Friction.	Shafting allowed to run hot.	All mechanical apparatus should be regularly inspected and lubricated where overheating may take place.

CHAPTER IV

POWER SUPPLIES

WHATEVER the form of power supply it must be adequate for the maximum demand including losses in transmission. The loading may be fairly constant as in the case of a machine shop, or it may be fluctuating as occurs with rolling mills. In both instances it must be obtained in the most economical manner.

Much of the detail work associated with power supplies is an engineering rather than a management problem. It is mainly electrical, but it includes gas, hydraulic, and compressed air services, and may also include auxiliary services.

Electric Power

The use of electric power should be regarded as an essential feature of modern factories, irrespective of the class of goods produced or the locality in which the works are situated.

The relative merits of public authority and private enterprise are very controversial. Normally, if a central power station is available, it will not be a paying proposition to put down an isolated plant of less than 500 h.p., unless all the exhaust steam from heating and process work can be utilized. Electricity from public supply, however, provides the most convenient power service, and when such a supply is available at a reasonable price, it may be assumed that it is the best source for either a large or small works. Even under unusual conditions, as, for example, a uniform and continuous demand, it will generally be found that a public supply is the best, as special terms may be obtainable. Nevertheless it is not wise to enter into a contract for public supply without making a careful study of the several scales usually available and the conditions applicable to each. An attractive scale is one which embodies a maximum demand and a minimum guaranteed rate of consumption, yet if business is estimated on too optimistic lines electricity charges may prove costly.

If a private generating station is decided upon, consideration will require to be given to the prime mover. This may be either (*a*) steam, (*b*) hydraulic, or (*c*) internal combustion. In each case the cost of power will include—

(1) Fuel.
(2) Water.
(3) Attendance.
(4) Supplies (oil, etc.).
(5) Interest on capital cost.
(6) Depreciation allowance.
(7) Maintenance.

The combination of a central station and a private plant may be advisable in certain instances. Such an arrangement offers two distinct alternatives.

(1) Average load obtained from central station and peak load generated

in own plant. This will give a high load factor and lower rates per unit from outside.

(2) Average load from own plant and peak loads and breakdowns, etc., from central plant. This gives a low load factor with higher rates per unit from outside though the total cost may be less.

Advantages of Electric Driving

Irrespective of whether the current is generated on the premises or is purchased from an outside source, the electric motor is undoubtedly the best driving power. Its advantages may be summed up as follows—

(1) It can be applied to individual machines without the use of overhead shafting and belts.

(2) As the power is not transmitted mechanically from a centralized point, losses are minimized and there is little wear and tear.

(3) Machines can be started and stopped with the aid of press buttons located in convenient positions.

(4) Motors of suitable types give the requisite speed variation.

(5) Power supplied to any particular machine or group of machines or department may readily be measured by meters connected in the circuits, and the effect of changes in processes can therefore be determined.

(6) By reason of their simple and robust construction electric motors cost very little to maintain.

(7) The drive is free from irregularities.

(8) Foundations, where required, are light and inexpensive.

(9) If it is necessary to change a motor it is generally a simple and straightforward job.

Central Power Stations

The improvement in the production of electricity is worth noting. A quarter of a century ago the amount of coal per unit generated was seldom below 3 lb. and to-day it is in the region of 1·25 lb. per unit generated. Power stations have attained to a thermal efficiency of 30 per cent, and the cost of production has gone down from 0·93d. to 0·1d. per unit. The records of production by authorized undertakings in Great Britain show that during the same period the total units generated annually have risen from 1500 million to 16,000 million. The plant installed represented about 1,000,000 kW., and to-day is over 8,000,000 kW.

The policy of the Electricity Commissioners in having encouraged the concentration of generation in fewer stations has justified the provision of much larger units, both of boiler plant and of turbo-alternator plant. Further, economy in production has been secured by operating power stations in groups, using two or three stations for supplying the base loads at high-load factors, while the remaining stations supply only the peak loads. Many stations consume more than 1000 tons of coal per day, and this warrants the installation of modern equipment with higher steam pressures and temperatures, thus effecting a large saving in the daily coal bill and fully justifying the capital expenditure. The tendency in this country has been to use temperatures up to 850° F., to

FIG. 30 TURBINE AND CONDENSER ROOM IN CENTRAL POWER STATION

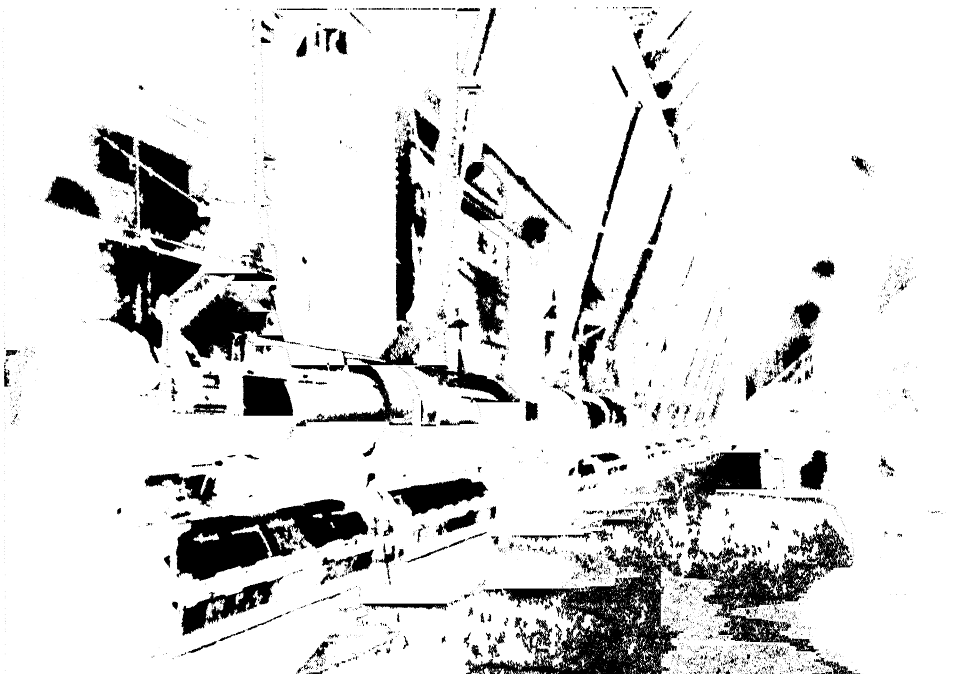


FIG 31 BOILER HOUSE OF CENTRAL POWER STATION SHOWING CHAIN GRATE STOKERS

limit steam pressures to 600 lb., and to avoid reheating.

The design of a modern power station, illustrations of which are given in Figs. 80 and 81, involves many difficult questions. The expenditure on boilers and the turbo-alternators at one time amounted to about 60 per cent of the total cost of the plant installed, whereas to-day the boilers and the turbo-alternators cost some 85 per cent of the total expenditure on plant, the balance being absorbed in switchgear, auxiliary plant for the supply of coal, water, and removal of ashes, etc. One feature is the operation of the boilers according to instruments which are located on control boards. Each boiler is provided with controlled superheaters to maintain the temperature of steam within 5 per cent under varying conditions of load. The overall efficiency of a modern boiler house is in the region of 90 per cent. The daily combustion of large quantities of coal raises the question of a possible nuisance to the public by the pollution of the atmosphere. Until a few years ago there was a tendency to use short chimneys with forced and induced-draught fans which, in some cases, created difficulties with soot and grit. It has since been proved that the emission of noxious materials can be prevented by practicable means, such as the use of high chimneys, the addition of plant for washing the flue gases, as well as by electrostatic methods of precipitation.

Makers of modern turbines are able to design plants consuming less than 10,000 B.Th.U. per kilowatt-hour, including bleeding for feed-water heating. The normal amount of steam bled with a 60,000 kW. turbine for feed heating and evaporating is about 25 per cent.

Electrical Equipment

Nowadays the 50-cycle alternator driven by a steam turbine at 1500 r.p.m. or 3000 r.p.m. is standard. Excluding water power, and the somewhat limited field of the diesel engine, there is no serious rival to-day to the steam turbine as a prime mover.

Power station alternators are generally wound for 11,000 volts, although some are built to generate at higher voltages, such as 22,000 volts. The increase of the transmission pressures to 66,000 volts and higher does, however, partly cancel the advantage these machines have in saving transformation losses. The power station generating equipment which has been developed during recent years is the turbo-alternator directly connected to its step-up transformer, the whole operating and being controlled as one unit. Transformers have made an equal advance in size to prime movers, and single units of about 90,000 kVA., constructed by British firms, provide the largest transformers in the world.

The Grid may be regarded as the outstanding monument of British electrical engineering and far-sighted national economic planning, and it has had a wide and beneficial effect upon the production of British electrical equipment. It is admitted by everyone that the quality of its transmission lines, transformers, and switchgear, its metering equipments and communication and control gear, is unsurpassed anywhere in the world.

Though direct current generation has declined, the use of direct current itself is still necessary, chiefly for traction, as this system is standard for all electric traction in this country.

Switchgear

Physical efficiency is not of great importance. The function of electrical switchgear is to provide facilities for holding the connections of lines and apparatus; the smaller the number of changes required the simpler can be the switchgear. The layout should be such that additions can be made without the disturbance of the original arrangements.

Distribution Systems

Whilst the cost of distribution is of ever-increasing importance, the cost of generation is much less than it used to be. The cost of distribution falls into two classes: (1) fixed charges, and (2) running costs. The former is dependent on capital cost, interest on capital cost, and depreciation allowance; the latter on repairs and general maintenance.

There are two classes of transmission, i.e. overhead and underground. There are no sharply defined reasons for the adoption of one or the other. If an overhead system is decided upon, it requires the sanction of the Ministry of Transport as well as of the local authority. Although overhead lines are more liable to interruption due to weather conditions, they may, owing to location, be the only method commercially practicable. Where an underground system is adopted it would appear that the cheapest method of laying cables is to bury armoured cables directly in the earth. As an alternative, ducts may be laid through which the cables can subsequently be drawn.

Distribution voltages have been determined by lamp voltages, 10 per cent having been frequently added for voltage drop in the mains.

Standard System of Distribution

The British Standard is a three-phase four-wire system at a frequency of 50 cycles per second, 400 volts between phases, and 230 volts between each phase and the neutral.

Substations for continuous current (or direct current) systems are equipped with rotary converters or rectifiers.

A common feature of industrial loads is poor load and power factors.

Load Factor

$$\text{The load factor} = \frac{\text{h.p. actually used}}{\text{h.p. of supply equipment}}.$$

It should be as high as possible so that less surplus equipment will be required to deal with customers' peak loads and thus actual charges will be proportionately less. A sliding scale of charges is usual, the charges decreasing with an increased current consumption. Included in such charges will be a proportion of the cost of the distribution system.

Power Factor

The power factor of a load has a great effect on a consumer's electricity bill, and where the power factor is low, a very considerable saving may be effected by raising its value. In Fig. 32, Curve *A* illustrates the way in

which the voltage of an alternating current supply varies during one complete cycle. Assuming the supply has a frequency of 50 cycles per second, then the voltage will pass through one complete cycle of variations in $\frac{1}{50}$ sec. This voltage, or electrical pressure, forces a current of electricity through the motor or what-

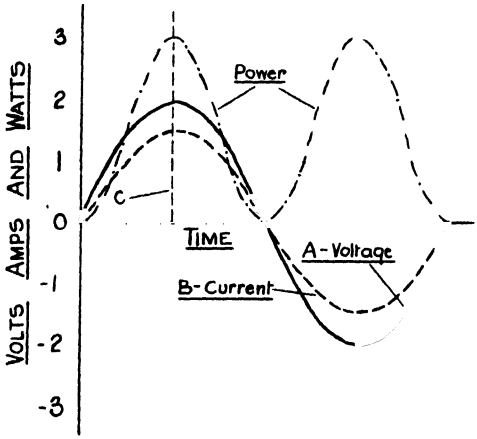


FIG. 32. CURVES SHOWING POWER FACTOR OF VALUE 1

ever apparatus is connected to the supply. Where the curve is below the zero line, the voltage is considered as negative, the voltage being reversed and tending to send the current through the circuit in the opposite direction. Since the force which is driving the current is varying, the current will vary and will go through a cycle of changes similar to that of the voltage in Fig. 32, Curve *B*.

An important fact is that whether or not the current reaches its maximum value at the same instant as the voltage reaches its maximum value depends upon the power factor of the motor, or whatever load is connected to the supply. If the power factor is unity, the current will reach its maximum at the same instant as the voltage, but if the power factor is less than unity the current will reach its maximum at some instant before or after the voltage, according to whether the power factor is leading or lagging. Fig. 33 represents the conditions for a

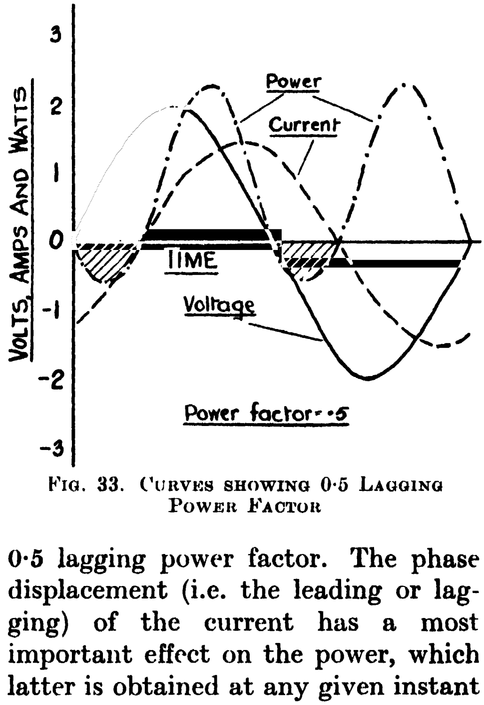


FIG. 33. CURVES SHOWING 0·5 LAGGING POWER FACTOR

0·5 lagging power factor. The phase displacement (i.e. the leading or lagging) of the current has a most important effect on the power, which latter is obtained at any given instant during the cycle by multiplying together the instantaneous values of the voltage (v) and the current (i). Thus—

$$\text{Power in watts} = v \times i.$$

Positive power is power which is being supplied to the motor from the mains, while negative power is that which is fed back by the motor to the mains. Thus when the power factor is unity, there is no feeding back of power, and this is the ideal condition. The lower

the power factor, the greater is the proportion of the power which is fed back to the mains.

The power received by a motor (positive power) is often called the apparent power and that which is actually used (positive less the negative) is called the true power.

$$\text{Power factor} = \frac{\text{True power}}{\text{Apparent power}}$$

Thus if a load receives 100 and feeds back 25, then—

$$\text{Power factor} = \frac{100 - 25}{100} = 0{\cdot}75.$$

The above relationship can be expressed in another form—

$$\text{True power} = \text{Apparent power} \times \text{Power factor}.$$

Therefore power factor may be defined as the factor by which the apparent power must be multiplied to obtain the true power.

Reliability of Service

This is mainly a matter of the relative location of the central station and factory, and the system of distribution. Maintenance and repairs should be of the same standard whether it is a private or a central plant. There should always be a reserve against breakdown, and for this purpose the installation of a diesel plant is frequently favoured. A central station has a large reserve except at high peak loads, and industrial loads come mainly between peaks. Only a boiler explosion wrecking the entire plant could put a central station out of commission, and modern boilers are not susceptible.

Fuel storage and service is dependent on the location of the plant. If on a main line railway or principal waterway, the reserve stock may be comparatively small, but if dependent on transport arrangements which are liable to interruption, particularly during the winter, larger stocks must be carried. In such cases interest on the outlay and cost of storage is a proper charge on power.

If a large supply of steam for heating and process work is required, the use of exhaust steam is generally best, the cost involved being confined to the interest on the power plant, maintenance, repairs, and attendance. In some cases, however, it will be cheaper to generate steam direct, and obtain electric power from the central station. Alternatively, condensing power units may be installed and heating, etc., effected by live steam or by "bleeding" from power units.

Power Distribution in Plant

The single motor main drive has a low first cost, otherwise it is a poor scheme and is a relic of the days of the steam-driven factory. It involves a main shaft, jack shafts and countershafting, belting and pulleys, and all these are power absorbing and comparatively heavy on maintenance.

Group Driving. This involves a separate motor to each line shaft. The latter may be in sections, i.e. groups of machines, each group having a separate motor. It involves a greater initial cost but gives increased flexibility, permitting sections of the shop to shut down. Furthermore, there is a better arrangement of machines, less shaft function, motors are better

proportioned to average load, and there is a higher load factor and efficiency.

Individual Drive. In this case a separate motor is required to each machine, the drive being effected through gears, silent chains, or a belt. The system gives maximum flexibility, but it involves a high initial

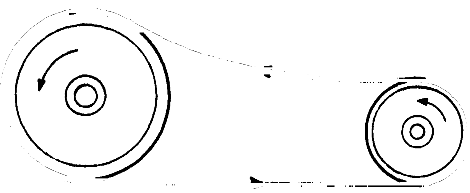


FIG. 34. CORRECT ARRANGEMENT FOR BELT DRIVE

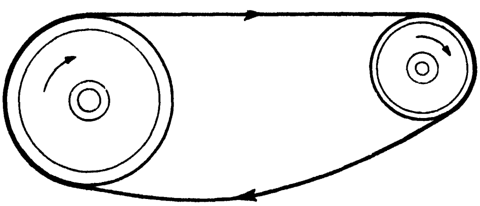


FIG. 35. WRONG METHOD OF BELT DRIVE

cost and increased motor h.p., each motor being capable of taking the maximum load of the machine. (In group driving some "averaging" is possible.)

Combination Drive. Machines requiring relatively constant power, e.g. automatic machines and turret lathes, may be arranged in groups, whereas those requiring carrying power, e.g. punch presses and heavy planers, may be equipped with individual motors.

It should be noted that whenever belting is used as the driving medium it should be arranged to drive as shown in Fig. 34, with the slack side of the belt on the top, and not as in Fig. 35, where the slack side of the belt is on the bottom. The reason for this is that the power transmitted depends on the arc of contact, and, as can be seen, this is much greater in the former case than in the second.

Hydro-electric Power

The British Isles are not among the most favoured parts of the world in respect of water power, and the abundance of coal has led to the neglect of what resources there are. Development has, however, proceeded on a modest scale and the present figure of about 500,000 h.p. is approximately ten times greater than it was some twenty-five years ago.

Pneumatic Power

Compressed air is widely used in most engineering factories and it is important that efficient plant should be installed to ensure an adequate supply at the desired pressure whenever required. It should be remembered that heat is generated during the compression of air, thus increasing the volume of the air. Accordingly, if air is compressed without removing any of the heat generated, greater power will be required to drive out the compressed air. If compression is carried out whilst the air retains all the heat due to compression, the operation is known as "adiabatic compression." If, however, compression of the air is carried out without any rise in temperature, the operation is known as "isothermal compression." This latter is the ideal arrangement, but in actual practice cannot be achieved. The manufacturer of compressed air plant applies various

methods by which he withholds the bulk of the heat as it is generated.

Air compressors are designed for single-stage, two-stage, and three-stage working (Fig. 36), stresses being very considerably reduced if the two latter are used where pressures of 100 lb. per square inch and higher are required. A large-capacity reservoir is a good investment and should always be included in the plant.

Air installations have a decided tendency to grow and it is advisable to install a large-diameter pipe in the first instance. Wherever possible, air pipes should be placed above the ground so that they may be inspected without any difficulty. A daily inspection should be arranged for all air pipes, air valves, and other equipment in the shops to ensure that leaks may be dealt with promptly. The effect of a leak will be realized when it is stated that air at a pressure of 100 lb. per square inch leaking through a hole of $\frac{1}{8}$ in. diameter will pass 25 cub. ft. of free air per minute and this corresponds approximately to 5 h.p.

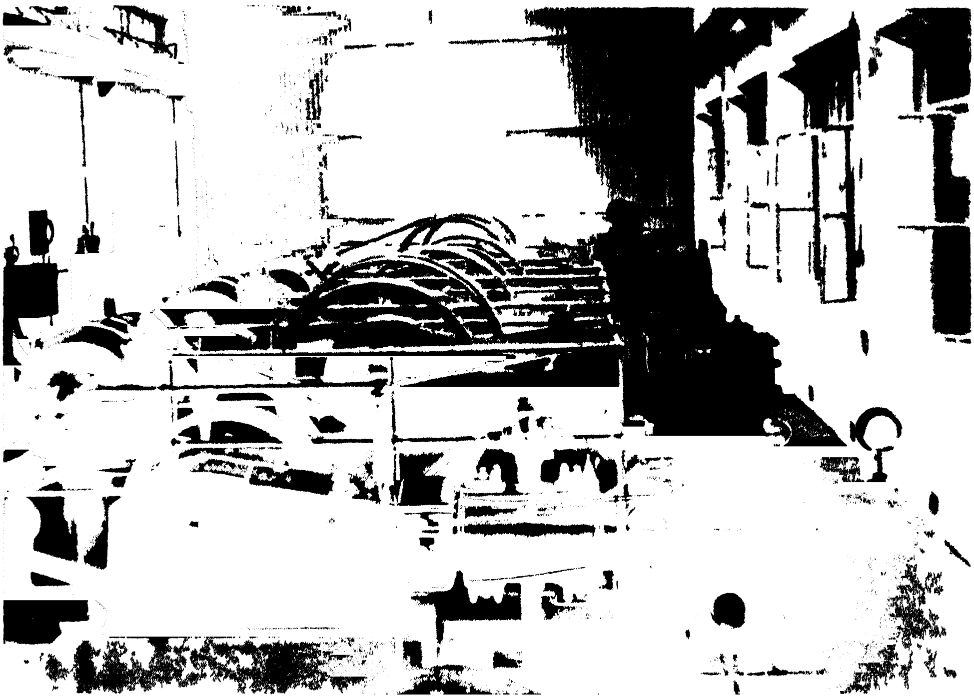


FIG. 36. AIR COMPRESSOR HOUSE

Containing one three-stage compressor operating at a discharge pressure of 1500 lb. per sq. in., and several 12 in. × 11 in., 9 in. × 8 in., and 5 in. × 5 in. single-stage compressors operating at 100 lb. per sq. in. pressure

Hydraulic Power

Many industries require hydraulic power for press work, cranes, elevators,

capstans, riveting machines, and similar work. The normal pressure at which water is delivered from the supply mains is, of course, totally

FIG. 37. VERTICAL SIX-PLUNGER HYDRAULIC PRESSURE PUMP, MOTOR DRIVEN

FIG. 38. VERTICAL EIGHT-PLUNGER HYDRAULIC PRESSURE PUMP, MOTOR DRIVEN

inadequate, and to obtain the requisite power it is customary for one or more hydraulic pressure pumps, according to requirements, to be installed. The types shown in Figs. 37 and 38 are probably the most widely used, but there are instances where it is preferable to use single units for individual presses.

Where the load is continually fluctuating hydraulic accumulators should be installed to ensure a reserve of power. In this instance a continuous delivery pump forces up the accumulator ram and to the latter is attached a dead load, often consisting of scrap metal.

Pascal's Law states that the pressure per square inch in the accumulator is equal to the pressure per square inch in the hydraulic press. Therefore—

$$\frac{\text{Total pressure on press}}{\text{Total load on accumulator}} = \frac{\text{Area of press}}{\text{Area of accumulator}}$$

Assuming the accumulator is loaded with 50 tons of scrap and has a ram of 8 in. diameter, and that the hydraulic press has a ram of 16 in. diameter, the pressure on the ram of the press will be—

$$\frac{P}{50 \text{ tons}} = \frac{\frac{\pi}{4} \times 16^2}{\frac{\pi}{4} \times 8^2} = \frac{16^2}{8^2}$$

$$\text{Therefore } P = \frac{50 \times 16 \times 16}{8 \times 8} = 200 \text{ tons.}$$

The hydraulic accumulator is a simple means of obtaining the power desired and such plant requires little attention.

Gas Power

Apart from municipalities and urban districts where towns' gas works have a steady market for the disposal of their principal product, namely gas, the installation of plant of this nature is not generally undertaken. Towns' gas plants utilize bituminous fuel, and the production and storage of gas

having high calorific value and having the impurities eliminated results in high capital cost. Storage in the familiar type of gasholder, which rises from a tank built of steel, cast iron, brick or concrete, is essential in connection with towns' gas generation.

For the running of isolated engines or the firing of furnaces, self-contained fuel gas plants are obtainable. These can be fed with anthracite, coke, wood or refuse which is sometimes a waste product of the factory, and units up to 500 b.h.p. capacity are obtainable. At the present time there is a tendency for the application of such producers to increase, and semi-portable units for various types of small heat-treatment furnaces where close temperature regulation is required are widely adopted. All these gas producers (other than towns' gas plants) work directly, without any storage unit between producer and using unit.

Where gas is used on a large scale for motive power and manufacturing processes, it will generally be supplied on more favourable terms than when it is required merely for heating and lighting purposes.

The quantity of gas used is measured in therms, one therm being equal to 100,000 British Thermal Units. To ascertain the number of therms used, the number of cubic feet registered by the meter should be multiplied by the declared calorific value (e.g. 500 B.Th.U.s) and divided by 100,000. For example—

10,000 cub. ft. × 500 = 5,000,000
which divided by 100,000 = 50 therms.

It is noteworthy that the gas referees prescribe that the results of the tests made by each officially appointed gas examiner shall be made available to the public in the following manner: A copy of his report for the preceding quarter, as forwarded to the local authority by whom he is appointed, shall be exhibited by the undertakers in each of their gas offices and showrooms and shall be forwarded to any consumer at his request.

Oxygen Supply

The distribution of this gas throughout a manufacturing establishment has for many years been limited to the method of transporting cylinders containing the gas at high pressure to the individual operators. Where, however, the gas is frequently or continuously required at one location it may be found profitable to install a piped service, the pressure at which such service shall be charged depending upon the class of work being performed, e.g. lead burning, welding, heavy cutting, etc. The pipe line may be fed from a single cylinder, a battery of cylinders, an oxygen producing plant, or from an evaporator which is charged with liquid oxygen by a contracting company.

Acetylene Gas Supply

The system whereby this gas is distributed in the factory depends in the first instance upon the type of distribution necessary to suit the working conditions, i.e. low pressure or high pressure. With the former, generation from calcium carbide is carried out on the factory premises either at a central position or in portable generators placed close to

the work requiring gas. From the fixed generator, distribution may be at a pressure up to approximately 15 in. water gauge through a piped service to all normal demand positions, but by boosting it may be increased to a somewhat higher pressure under approved conditions.

By the high pressure method acetylene gas is supplied to the using point either compressed in cylinders of convenient size from which the operator takes his supply direct, or by the provision of a piped service which is charged from one or a group of acetylene cylinders. A somewhat purer gas, which is essential for certain types of welding, is furnished by this method.

Painting of Pipes and Conduits

It is strongly recommended that all the piping, conduits, ducts, and cables throughout the factory should be painted in accordance with the B.S.S. This system enables inspection to be carried out more readily and makes mistakes less likely.

The complete list is given below for convenience—

Type of Service	Standard Colour
Air	White
Drainage	Black
Electricity	Orange
Gas	Deep Cream
Oil	Light Brown
Refrigeration	French Grey
Steam	Crimson
Water	Azure Blue

Maintenance

The necessity for the systematic maintenance of all power equipment cannot be over-estimated. Boiler scale, valve leakages, slack bearings, loose belts, worn gearing, etc., are all to be avoided, and this involves routine inspection. It should be remembered that preventive repairs are always less expensive than breakdown repairs, more especially if the latter must be effected outside ordinary working hours.

CHAPTER V

HEATING AND VENTILATION

THE adequate heating and ventilation of industrial buildings can scarcely be over-stressed, these factors having a vital bearing upon the welfare of the occupants. The ideal to be aimed at is to design heating and ventilation installations so that the most suitable temperature and humidity conditions can be given and that proper air-movement, as apart from giving a specified interchange of air, can be ensured without appreciable draughts.

Heating in Industry

All industrial buildings require to be heated during the winter months, some to comply with factory regulations, some for reasons of manufacture, but the majority in order to ensure the comfort and well-being of the staff, without which the quantity and quality of production will rapidly deteriorate. The primary object of heating is not, as may be supposed, the heating of the body itself, but the prevention of a too rapid loss of heat from the body to the surrounding air and to exterior objects, by air contact, radiation, and evaporation. The object of heating, therefore, is to maintain such a temperature as will permit of a normal loss of heat.

The human body is continuously generating heat, and to maintain the normal temperature of health and comfort conditions the body must also give up heat continuously. It has been stated that the amount of heat generated by the human body in still air at 70° F. varies approximately from 400 B.T.U.s per hour, in the case of a sedentary worker, to 1300 B.T.U.s per hour for a man doing heavy manual work. Normally, the cooling of the body is effected in two ways, i.e. by imparting heat to the air which comes into contact with the clothes and body, and by the evaporation of moisture from the skin and the respiratory surfaces; in other words, partly by radiation to colder surrounding objects and partly by convection.

In some workshops, foundries, forges, steam laundries, etc., where the operations carried on are attended by the generation of heat in furnaces or stoves, allowance must be made for this, and the temperature fixed according to the work to be performed.

It will at once be appreciated that different types of buildings require entirely different treatment, and that the materials of which the buildings are constructed must be taken into account. The heat losses vary greatly, not only according to climatic conditions and the nature of the work being performed, but also according to the structure of the walls, whether of cement, brick, timber, iron, etc. The area of glass and nature of flooring are also important items to be considered.

When considering the installation of a heating system it is advisable to do

so before the plans of the building are completed, as it will be found much easier to design a satisfactory plant at this stage than to design a plant to suit existing conditions.

In the modern factory there is usually a large window surface, and as a result more heat is required to maintain an adequate temperature than in the earlier type of small window factory. It is important always that artificial heat should be introduced at as low a level as possible.

The problems are so varied that only those who have had an extended experience in all classes of buildings are in a position to design really efficient apparatus. For this reason it is always worth while obtaining the services of an efficient heating and ventilation engineer.

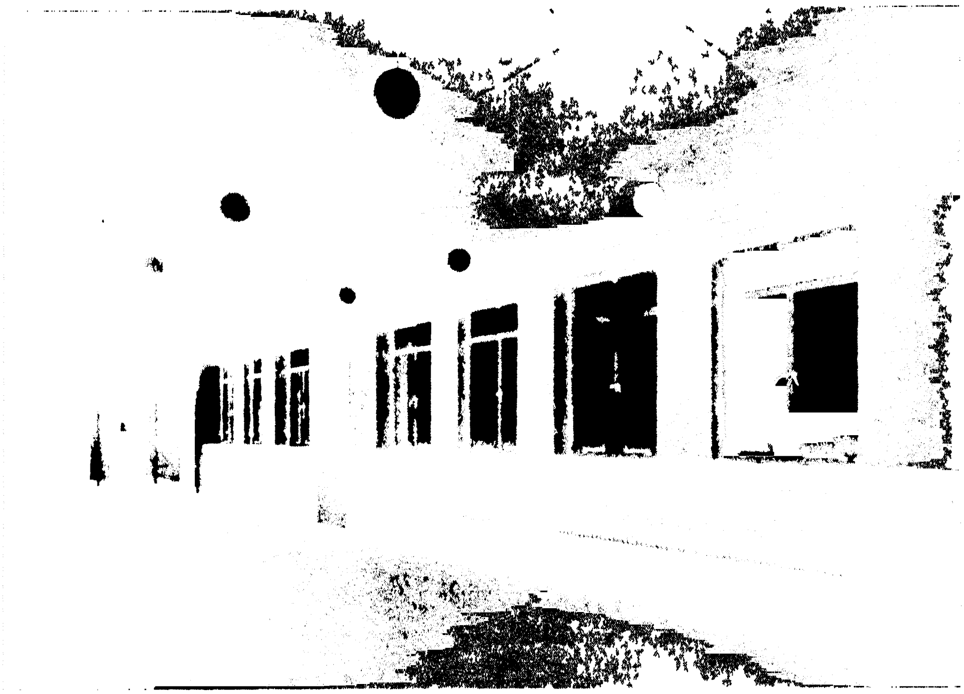


FIG. 39 CANTEEN IN A LONDON FACTORY SHOWING DIRECT HEATING AND INLETS FOR TEMPERED AIR SUPPLY AT HIGH LEVEL

Hot Water Heating

For the heating of warehouses and offices, hot water systems are the most widely used. The method of application may be either the low-pressure, high-pressure, or accelerated system. With low-pressure hot water heating, the heating surface may consist of piping only, or a combination of piping and radiators. The latter is the more suitable arrangement for offices, each radiator being under individual control (Fig. 39). This is the most widely used system for general

purposes, being simple to operate and reliable.

High-pressure hot water heating is inexpensive, economical, and easily operated. The pipes are small and unobtrusive and may be adapted to any building. The plant is centrally controlled from the boiler, local control not being possible. This system is frequently used for drying rooms.

For larger buildings, accelerated hot water heating is widely adopted, the circulation being mechanically accelerated by means of a motor-driven pump. This allows smaller mains to be used, gives more freedom in design, requires a shorter warming up period, and maintains uniform temperature throughout the building. When properly designed, gravity circulation may be utilized during the night, the accelerator being started up when full heating is required.

For lofty buildings, heating combined with ventilation is the most satisfactory method. For multi-story buildings there is much in favour of low-pressure steam. High-pressure steam is, however, frequently used because it is employed for other purposes, but the high temperature of the steam is often objectionable since it causes disassociation of dust and a consequent unpleasant odour. There

FIG 40 OIL-FIRED HEATING BOILER INSTALLATION

Fig. 41. Floor Type Unit Heater with Special Outlets

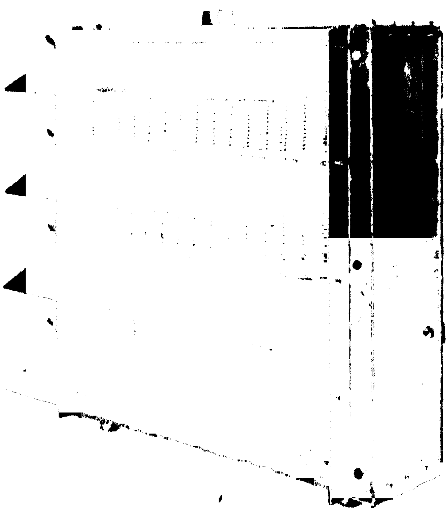


Fig. 42. Overhead Type Unit Heater
(*front view*)

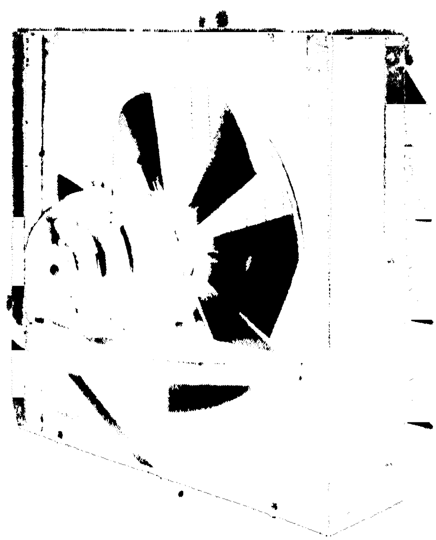


Fig. 43. Overhead Type Unit Heater
(*rear view*)

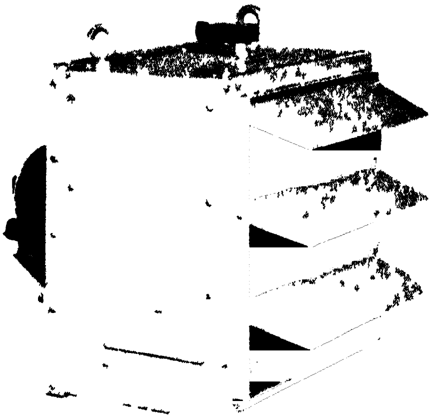


Fig. 44 Electrically Heated Suspended Type Heater Unit (*front view*)

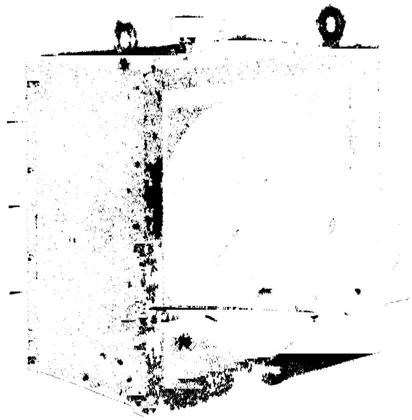


Fig. 45 Electrically Heated Suspended Type Heater Unit (*rear view*)

Fig. 46 Overhead Type Unit Heater Installation

(*Note* Some are recirculating units and others have controlled fresh air inlets)

are several types of boilers for heating purposes, and these may be fired by coal, coke, oil (Fig. 40), or gas.

Utilization of Waste Heat

Exhaust steam is often utilized for heating purposes. In most works there are, in addition, other sources of

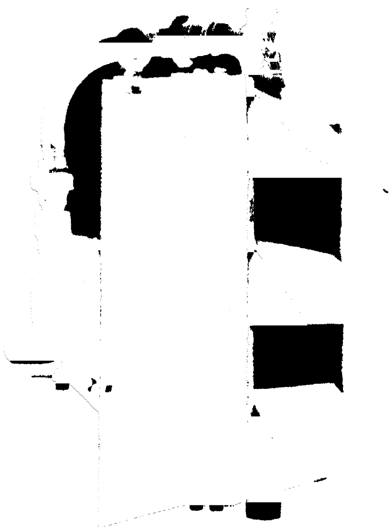


Fig. 47. Overhead Type Unit, Steam Turbine Driven

surplus heat which can be made available. In iron and steel works furnace gases are passing off at high temperatures, and offer wide scope for use in waste heat boilers. Every intermittent kiln, whether for brick, fireclay, pottery, or other ware, offers considerable scope for heat recovery. Of the heat generated, some 60 per cent or so is absorbed in heating up the material to be fired and the kiln itself. This accumulated heat can be recovered during the cooling period and utilized for warming or drying purposes. Besides these examples, there is surplus heat available from enamelling ovens, muffle furnaces, cloth finishing machines, and other similar equipment.

Unit System of Heating

The development of the unit system of heating is a noteworthy contribution to present-day industrial efficiency and advancement. Small units allow for varying conditions and they also meet the wishes and feelings of individual operatives, while there is certainly less opportunity for workers to tamper with the installation if it is overhead. Other advantages which may be claimed for the unit heating system are as follows—

(1) It is easy to install.

(2) The first cost is low.

(3) Rooms are heated quickly.

(4) Warm air is deflected where desired.

(5) The same fan will circulate cool air in summer-time.

(6) It is easy to move to a new position.

Figs. 41 to 47 illustrate the different types of unit heater met with in practice. Before going into further detail regarding combined heating and ventilating systems, however, it will be as well to consider ventilation.

Air Movement

A stagnant atmosphere is one of the main causes of mental and physical inefficiency in industrial operations. This has been closely investigated and is clearly demonstrated by the various reports of the Industrial Fatigue Research Board issued by the Medical

Research Council. It is during the summer months that the lack of ventilation and the absence of air movement are most severely felt. For this reason an effective system of ventilation or air circulation produces the most gratifying returns at this season of the year.

The movement of air is extremely important to physical well-being, the absence of air impurities and the provision of a large air space per individual not, in themselves, being sufficient. The temperature in every office and workshop should not be uniform and monotonous but should vary during the day in different parts of the building, thus ensuring a change in the atmosphere. It is essential that the air should be kept moving, and it should preferably be cool and dry rather than damp and hot.

Natural Ventilation

For efficient ventilation there must be openings of adequate size in suitable positions for the inflow and outflow of air. In small rooms ordinary doors and windows provide the inlets and the chimney flue the outlet, and these are generally satisfactory. In larger rooms the windows should be fitted with "hoppers" at a low level and swing windows at a higher level. For examples see Fig. 48.

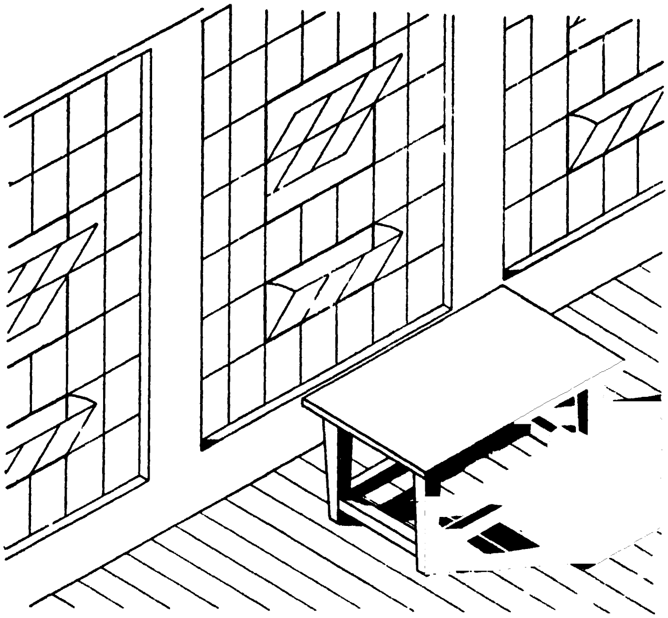


FIG 48. HOPPER AND SWING WINDOWS

Circulating fans have much to commend them in offices and small workshops where the existing ventilation needs improvement. There are various types of portable and suspended fans, similar to those illustrated in Figs. 49 and 50 respectively.

Outlets in the form of roof ventilators (Fig. 51) are frequently used, but where down-draughts occur due to the wind, the pitch of the roof, or the location of the building, the volume of air extracted tends to be reduced if an endeavour is made to counteract the trouble. A very successful type of roof ventilator is illustrated in Fig. 52. It provides free outlet for the air and makes effective use of the action of the wind passing horizontally across, to maintain extraction.

The revolving cowl type of roof extractor requires to be carefully constructed, accurately balanced, and well lubricated if it is to give satisfaction, and for this reason the fixed type is usually preferred.

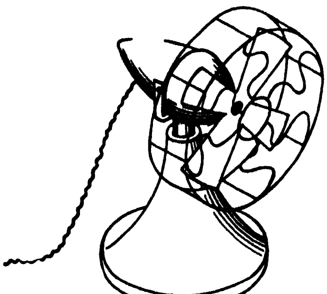


FIG. 49. PORTABLE ELECTRIC ORBIT FAN

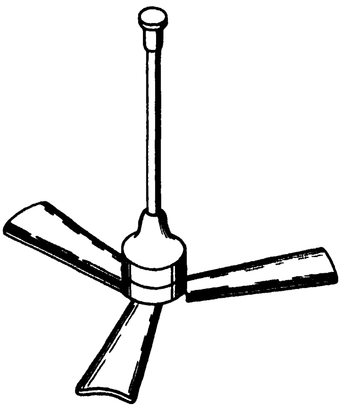


FIG. 50. SUSPENDED ELECTRIC AIR CIRCULATING FAN

Working Temperatures

In the British Isles it is customary to maintain the following temperatures inside the buildings when the outside temperature is 32° F.—

Workshops in which heavy work is carried out . .	48-50° F.
Workshops in which light work is carried out . .	52–55° F.
Offices	60-65° F.

Production is directly dependent upon atmospheric conditions, poor air having an adverse effect on the vitality of employees, and in some instances also on materials and machines. Nor is the latter confined to small tools and

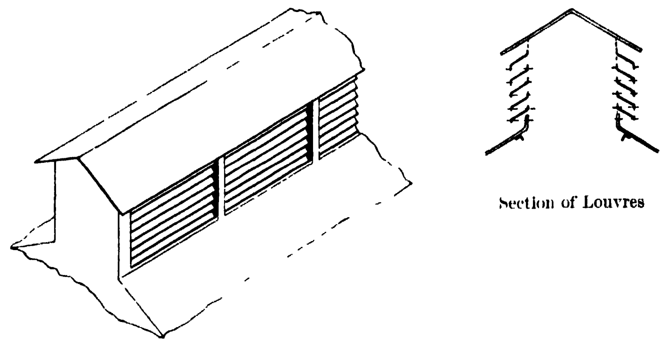


FIG. 51. DOUBLE-SIDED RIDGE LOUVRE VENTILATOR
(Extends the whole length of the roof and thus provides a large extraction area.)

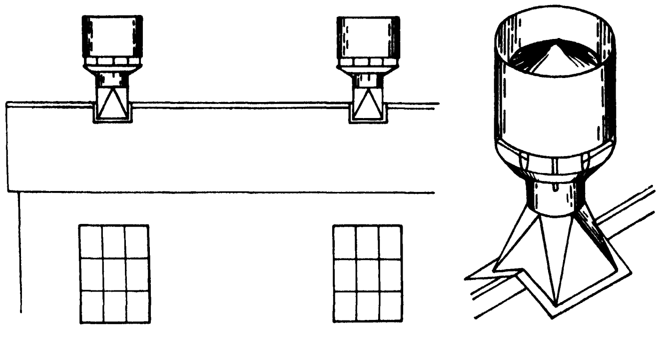


FIG. 52. ROOF OUTLET VENTILATORS
(Circular fixed type)

equipment, Fig. 53 being an example of a large hobbing machine which is completely enclosed in an air-conditioned room in order to ensure accuracy of work.

The provision of reasonably pure air at a comfortable temperature and humidity is an important factor to the well-being of workers. It is also of

importance that the atmosphere shall not be too stagnant, even if it is otherwise satisfactory. The need for purity and warmth is well known, but humidity and air movement are also important. Unless the moisture content of the atmosphere increases with the temperature there will be a feeling of dryness, and conversely with a drop in temperature a feeling of dampness.

Although everyone is aware of the drowsy feeling which can be experienced in a room in which the air, even though cold, is perfectly still, it is not everyone who takes the action necessary to improve matters, though they may be in a position to do so. Some air movement is required to carry away the evaporation from the skin, and while this is often provided by the movement of the worker or of machines, there are many cases of sedentary work, especially clerical and assembly operations, with which some artificial air movement is desirable. Draughts are to be avoided, especially by sedentary workers, and it will be found that workers of this class will prefer a static unpleasant atmosphere to draughts.

The working conditions in glass works, tinplate works, and rolling mills are such that a very strong movement of air is necessary to produce conditions of comfort for the operatives. Exposure to extreme radiant heat is a severe test of physical fitness, but an adequate supply of cool air suitably delivered enables maximum output to be maintained over long periods. The sensation of coolness depends upon the rate of evaporation of moisture from the skin. This being greatly accelerated by properly

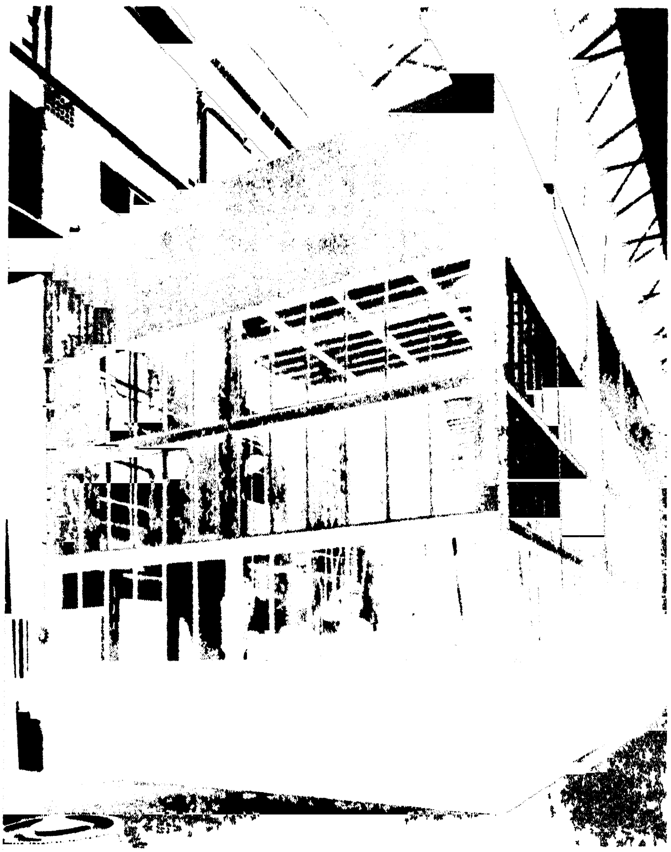


FIG 53 LARGE HOBBING MACHINE ENCLOSED IN AIR CONDITIONED ROOM

directed air currents, comfort is maintained under conditions in which work would otherwise be almost impossible.

Measures must be taken to maintain a satisfactory temperature, and at the same time the ventilation must be such as will not interfere with the purity of the air. Dust and soot which may enter the room with air required for ventilation should be excluded by washing or filtering the incoming air.

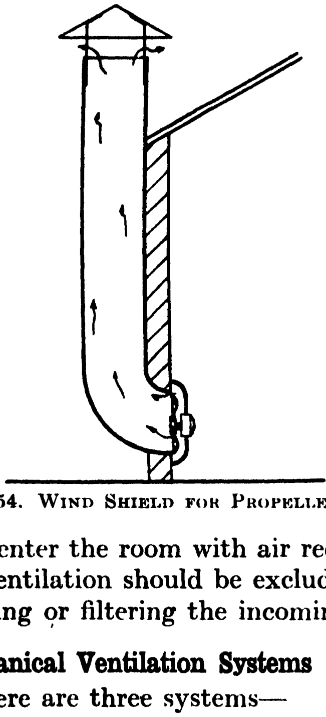


FIG. 54. WIND SHIELD FOR PROPELLER FAN

Mechanical Ventilation Systems

There are three systems—

(1) Extraction.

(2) Plenum.

(3) Plenum combined with extraction.

Whatever the system adopted it should be effective at the working level.

Extraction. The impure air is removed by fans and the fresh air enters at inlet points remote from the fans. Extraction systems are very effective in narrow rooms. Short circuiting should be guarded against, and wind shields and ducts similar to those indicated in Figs. 54 and 55 respectively, and fitted at a distance away from the fan not less than the fan diameter, should generally be provided. This is an excellent arrangement for buildings of more than one story, providing that the shield is not made to slope as shown by the dotted line in Fig. 55.

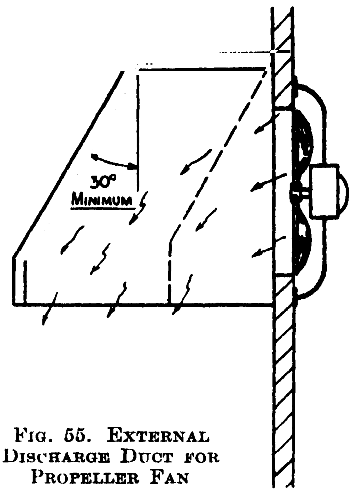


FIG. 55. EXTERNAL DISCHARGE DUCT FOR PROPELLER FAN

Propeller fans are usually favoured for extracting air and are extremely efficient, being capable of moving large volumes with a small expenditure of power. On the intake side air is drawn from all the surrounding area and is propelled forward at a high speed for a considerable distance on the discharge side.

If V is the volume of air discharged in cubic feet per minute for a particular type of fan, D the diameter across the blades, and N the number of revolutions per minute, then—

$$V = kD^3N$$

where k is a constant (about 0·6, depending on the design).

Whenever a discharge of a certain standard has been decided upon, the formula should be applied to obtain the number, size, and speed of fans required. It may be helpful to note the figures shown in Table I, the first two columns being based on good average practice in fan design, and the third column having been arrived at by use of the formula.

TABLE I

VOLUME OF AIR DISCHARGED BY FAN

Diameter (feet)	Average Speed (revolutions per minute)	Volumes Discharged (cubic feet per minute)
1	1,700	1,020
1½	1,125	2,300
2	840	4,030
2½	675	6,320
3	560	9,075
3½	475	12,230
4	420	16,130
4½	390	21,320

Viewed from the driving side, a fan is said to be right-handed (R) if its direction of rotation is clockwise, and left-handed (L) if counter-clockwise. There are eight alternative positions of outlet which are indicated by figures in Fig. 56. With any of these the direction of rotation may be either clockwise or counter-clockwise, thus giving sixteen alternatives and meeting all requirements.

To prevent the air from being impeded, the fans should not be fitted to walls where winds prevail.

Wherever ducts are necessary they should be short and free from projections, with gradual bends, and in no circumstances should the cross-section of a duct be less than that of the fan disc.

Plenum. This system is always adopted where complete air conditioning is desired. Where it is used in factories, however, the air supply is not usually given any treatment other than being warmed. Centrifugal fans or pressure fans are used and are designed to move larger volumes of air against resistance, particularly those set up by extensive ducts.

The excess of pressure on the discharge side of the fan is called the static pressure, and this is utilized to overcome the resistance offered by ducts. It will thus be realized that the resistance must be carefully estimated and a fan selected which will give the desired air volume. If the static pressure is increased, the volume of air will be decreased, and vice versa.

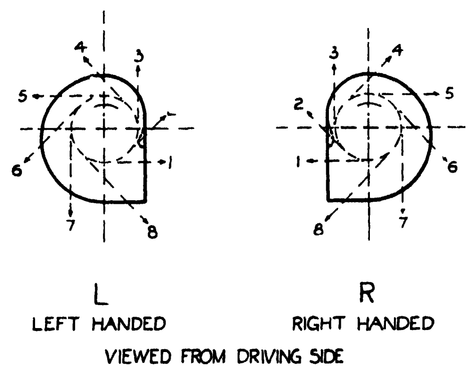


FIG. 56. POSITIONS OF FAN OUTLET

Accordingly, it is not possible to give a law comparable to that of the propeller fan, and it is usual for manufacturers to carry out a test for a particular fan at a constant speed, varying the pressure and noting the volume of air passed through. If the results are plotted, the curve obtained is called the characteristic curve of the fan. Static pressure is registered by

water gauge, one inch on the gauge representing an approximate pressure of 5 lb. per square inch. It should be noted that the volume of air delivered by any centrifugal fan is directly proportional to its speed, i.e. if the speed be doubled, the volume of air is doubled.

Again, the air pressure or static water gauge set up by a fan is proportional to the square of the speed, i.e. if the speed be doubled, the air pressure will be increased four times. Also, the power absorbed by a fan is proportional to the cube of the speed, i.e. if the speed be doubled, the power will be increased eight times. The fan, therefore, which will give the most efficient results will be that which will deliver the required air volume at the necessary pressure to overcome the resistance of the circuit with the least

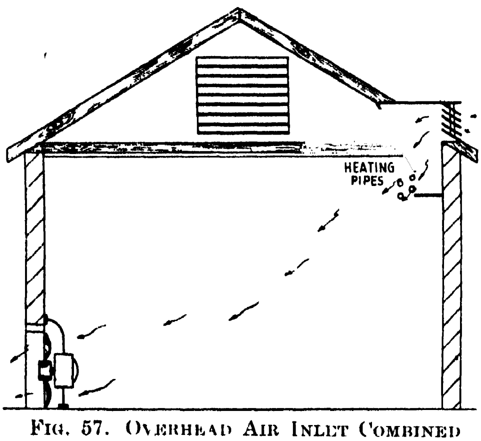


FIG. 57. OVERHEAD AIR INLET COMBINED WITH HEATING PIPES

expenditure of power. It is uneconomical to use small high-speed fans and small ducts. Fan manufacturers usually give the speeds, volume of air discharged, and brake horse-power required for varying fan wheel diameters and static pressure.

Plenum Combined with Extraction. Ventilation is best controlled when both the air supply and extraction are effected mechanically, although it is extremely important that the extraction positions are suitably arranged relative to the plenum inlets.

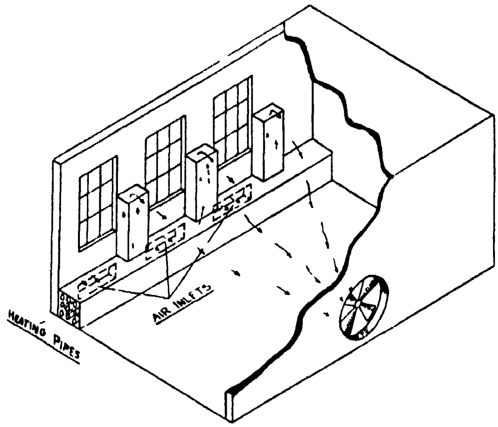


FIG. 58. LOW LEVEL AIR INLET DUCTS WITH HEATING PIPES

Combined Heating and Ventilating Systems

A properly planned system of mechanical ventilation utilizing electrically operated fans, together with adequate heating arrangements, is necessary in most buildings, particularly during the winter period when windows and doors are all closed to keep the air warm or to avoid draughts.

Preheating of the air supply is not common with extraction systems, whereas it is the accepted practice with the plenum and plenum combined with extraction systems. The air is drawn or blown by the fan through hot water pipes, coils, a radiator steam or exhaust steam battery, or gas or electric systems. Inlets combining air-warming devices are shown in Figs. 57 and 58.

Fig 59 Plenum Heating and Ventilating Plant in an Electrical Instrument Works

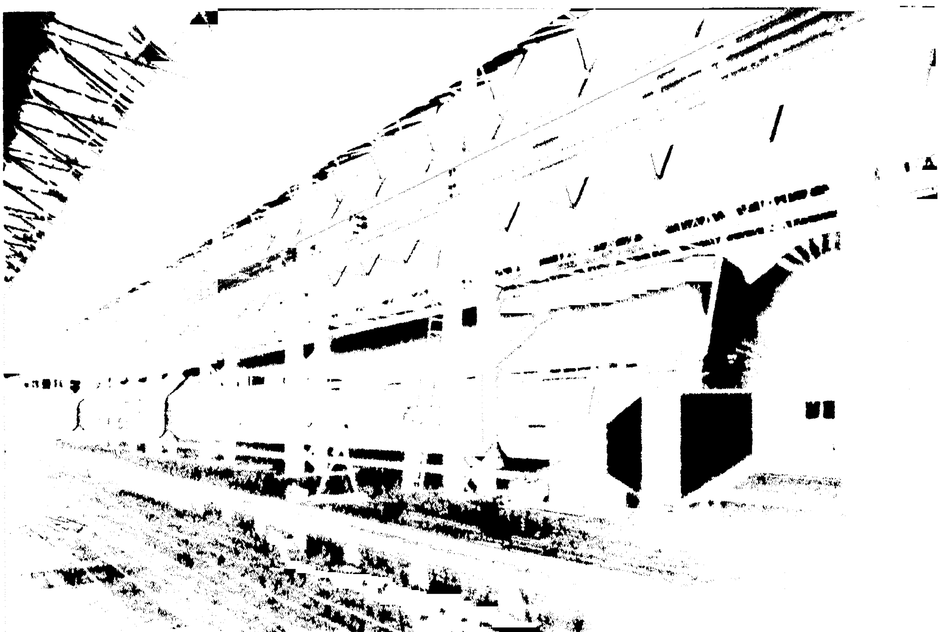


Fig 60 Plenum Heating Installation in a Railway Running Shed

Where sheet steel ducts are used, as in most factory buildings, air is sometimes delivered overhead and sometimes near the floor level, this depending upon the height and general construction of the buildings. Each case must be considered on its merits, but usually high buildings necessitate the use of downcomers (Figs. 59 and 60) to deliver the air at the working level of the operator. Except in very large buildings the whole of the duty of heating and ventilating can be performed by one plant (Fig. 61), but where the premises are very extensive it is usual to divide the plant into several units.

The plant or plants should be centrally situated and comprise fan, heater, and an air filter where this is necessary. The drive to the fan can be taken from existing shafting, or it may be driven by a separate motor. Where steam is available, a steam engine drive is the most economical, the exhaust steam being utilized for heating purposes. If no steam is available, a direct fired heater can be utilized, though this does not give the same ease of control.

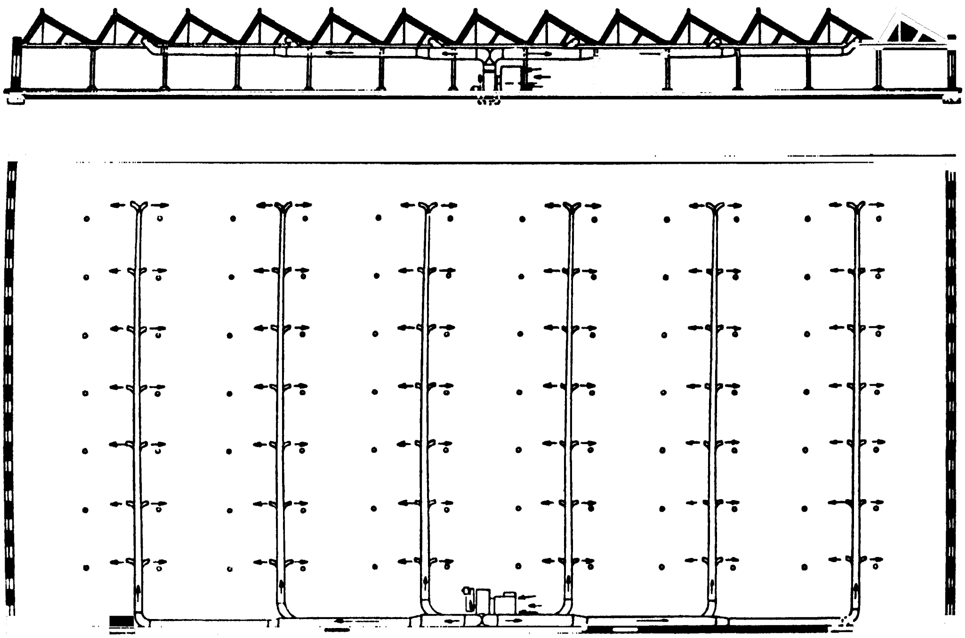


FIG. 61. ARRANGEMENT OF HEATING AND VENTILATING PLANT

For the majority of factories, provided they are free from gas and high temperatures, not less than six complete changes of air per hour will prove satisfactory. If during the winter the cost of heating will prove too expensive, apparatus must be installed which will ensure adequate air movement. In warm weather the air is normally changed more frequently by the natural flow of air through the windows and ventilators, if these are

suitably distributed. For this purpose there should be at least 5 sq. ft. of opening per 100 sq. ft. of floor area.

Undesirable draughts should be avoided by having the inlets properly placed and of sufficiently large area, with a maximum air speed of 250 ft. per minute.

With the modern type of steel-framed construction and thin walls, heat losses will be greater and in winter a higher temperature than the normal temperature may be required. As already mentioned, however, too much attention must not be paid to the thermometer. It is the amount of air movement which is much more important. An instrument by which the measurement of air velocities may be ascertained is the katathermometer. The air velocity is calculated by measurements of the rate of cooling of the katathermometer and of the air temperature. With the standard katathermometer the rate of cooling from 100° F. to 95° F. is observed. At the working position of a sedentary operator, the average temperature being 60° F. to 65° F., the air velocity should be 20 to 30 ft. per minute. For heavy muscular tasks or for high working temperatures, proportionally greater rates of air movement are necessary.

Data Required

The following preliminary information will be required where any heating and ventilating installation is under consideration—

(1) Internal temperature to be maintained in winter.

(2) Minimum external temperature in winter.

(3) Whether live steam is available. If so, pressure and quantity.

(4) Whether exhaust steam is available. If so, pressure and quantity.

(5) Proposed method of driving.

(6) Whether electricity is available. If so, whether alternating or continuous current, giving phase, periodicity and voltage if alternating, or voltage if continuous.

(7) Number of employees, and whether special ventilation is required in any part to counteract obnoxious fumes.

(8) Whether the plant is for use in the daytime only, or can be run continuously day and night in the coldest weather.

(9) Drawings to enable the heat losses to be calculated. These should show the extent and description of the various exposed surfaces, such as walls, windows, floor, roof, and skylights. Adjoining rooms which are already heated should be indicated, and if any particular position for the apparatus is preferred this should also be included.

Automatic temperature control is an important addition to any heating installation, and as manual control is not satisfactory it is best that the human element should be eliminated by the installation of thermostatic controls operating simple relay switches which start and stop the fan motors according to the temperature maintained. This results in economical running of the installation.

Modern conditions in industry call for a simple form of heating and ventilating apparatus which, while satisfactory for present needs, can readily

be adapted to suit possible alterations and additions to the factory itself.

Dust Collection

The necessity for extracting dust from the air is a feature which is closely allied to ventilation. A great variety of industries produce, during their manufacturing processes, large quantities of fine or coarse dust which must be collected (1) to safeguard the health of the workers, particularly against silicosis, (2) to protect valuable machinery, and (3) to prevent nuisance and damage to surrounding property. In some cases it is insisted upon by legislation, whilst in others the dust is valuable and its collection is therefore not only a question of health but is a profitable investment.

FIG. 62. DUST-COLLECTING PLANT

In designing dust-exhausting apparatus, hoods or hoppers usually have to be devised which will suit individual machines without obstructing the operator or interfering with the accessibility of removable or adjustable parts. Conveying pipes must also be proportioned so that the dust is exhausted equally well whether a machine is close up to the fan or at the farthest end of the system.

The choice of a suitable dust-collecting plant is mainly dependent on the nature and size of the dust. For coarse material containing a small percentage of fines only, such as wood chips, saw-dust, leather, etc., a cyclone separator, which gives a satisfactory degree of efficiency, is generally used. This type of dust collector is, however, not efficient for the collection of very fine dusts, and in many cases a combination of cyclone and cloth filter is employed. For small air volumes this is a good arrangement, but for large capacities the plant becomes unwieldy and occupies too much space. Where comparatively large air volumes have to be dealt with, therefore, an automatic bag type dust collector is probably the only satisfactory solution.

The plant shown in Fig. 62 comprises three dust collectors, each serving the vent of a closed circuit grinding equipment. The inlet to the dust collector is on the far side, the near side showing the inspection doors, top and bottom, and the operating gear on top of the collector. The plant is very compact and readily accessible. The dust collector hopper is below the platform, fitted with spiral conveyer and star feed valve discharging the collected dust to a belt conveyer.

CHAPTER VI

INDUSTRIAL LIGHTING

The enthusiasm of employees is quick to respond to improved working conditions, both the quality and quantity of work increasing accordingly. Particularly does this apply to lighting conditions, and one of the best investments that can be made in the factory is to ensure that both the natural and artificial lighting conditions are thoroughly satisfactory.

The eyes are undoubtedly the most delicate organs of the human body, and they must be given every consideration if continued and efficient service is to be obtained.

Briefly, defective lighting has the following disadvantages—

(1) Increased liability to accidents owing to the inability to see objects distinctly.

(2) Spoilage and scrap.

(3) Poor "atmosphere" and lessened cleanliness.

(4) Failing eyesight and health of employees.

Unless proper precautions are taken the universal use of high-speed machinery tends to increase the risk of accidents owing to the inability to see objects distinctly, and an increased liability to accidents not only creates a sense of apprehension in the mind of the employee and tends to accentuate industrial fatigue, but this feeling of apprehension inevitably slows down his efforts and impedes production. From a study of official records of industrial accidents it is observed that the percentage of industrial accidents is found to be considerably higher in the winter than in the summer months, so that the darker days and inefficient artificial lighting undoubtedly have a material bearing upon these conditions.

Natural Lighting

Nature's principal source of light is the sun. On a clear day it illuminates surrounding objects to such an extent that the light reflected from these objects is frequently harmful. If it is a dull day the sky diffuses the direct rays, thus forming a more pleasant degree of illumination and actually better visibility because the faculty of vision is not strained. In the eye the size of the pupil regulates the quantity of light which enters, and when the light is brilliant and shines directly into the eye it tends to contract the iris, making it difficult to see and reducing visibility. Under proper lighting conditions, where only reflected and diffused light enters the eye, the iris is extended normally, ensuring greater visibility and freedom from eye-strain.

Indoors a certain amount of sunlight is always welcome, but when the sun is too strong portions of the windows on the south side should be shaded and all roof-lights temporarily whitened.

Rays of natural light are either direct or reflected. Daylight is pleasant but its intensity depends on the season, locality, and time of day, and no "control of the source" is possible. The advantages of good natural illumination should be obvious, and in deciding on the number and size of windows the following points need to be considered—

(1) General construction of windows, especially with regard to area.

(2) Proximity, character, and colour of adjoining buildings.

(3) Height and width of rooms.

(4) Provision of open spaces in layout.

The total window space should be from 20 per cent to 35 per cent of the floor space. Windows may be lateral, they may be roof windows, or they may be a combination of the two. Roof lighting is, of course, only possible for the top floor of multi-story buildings, or for single-story buildings. The north light or "saw tooth" roof, in which the glass faces north, gives a quite uniform illumination.

In these days, large airy steel-framed windows are much favoured. These are cheaper than walls, though not so resistant to cold, they are adaptable to ventilation, are fire resisting (more especially when combined with fire-resisting glass), and they give straight lines which are architecturally correct. Lateral lighting is normally equivalent to 100 foot-candles and is only effective for widths of 40 ft. to 60 ft. (illumination at the centre being about 1 foot-candle). It should be noted that—

(1) Daylight factor

$$= \frac{\text{Actual illumination at any point}}{\text{Illumination of horizontal surface exposed to complete hemisphere of sky}}$$

(2) Sill ratio

$$= \frac{\text{Actual illumination at any point}}{\text{Illumination that would reach sill of unobstructed window}}$$

The average sky brightness in towns is 500 foot-candles. The daylight factor may be as low as 0·2 per cent, below which supplementary artificial lighting is necessary for adequate vision. A minimum daylight factor of 1 per cent to 2 per cent and a sill ratio of 2 per cent to 4 per cent are desirable.

Ordinary glass absorbs 4 per cent of light. Ribbed glass (which is opaque) absorbs 10 per cent but refracts the rays of light and distributes them more horizontally than ordinary glass.

Any darkening of roof-lights which is considered desirable for the elimination of glare during the summer period should not exclude too much light, as dull days must also be taken into consideration. Outside whitewashing will usually meet the case satisfactorily.

So far as the interior painting of walls is concerned, it should be remembered that flat tones absorb the light whilst enamels reflect. Too much reflection is not, of course, desirable as it results in glare. The coefficients of reflection of various surfaces are given in Table II.

Modern Standards

In existing multi-story buildings of great width in proportion to height from floor to top of windows, or where the space is narrow between blocks of buildings, the lighting should be

compared with modern standards. The maximum width of modern buildings should not exceed five times the height from floor to top of window, and the width between the blocks should be great enough to allow a ray of light passing the top edge of the roof of one building to penetrate well into the interior of the ground floor of the nearest building. This condition will usually be met by making the width of open space between buildings not less than the building height. Where these conditions do not apply, additional light may be reflected into the interior either by outside reflection or by special ribbed glass. Both methods are effective if the reflecting surfaces are kept clean. Window cleaning is commonly neglected, especially with roof-lights, and this is a very bad feature. A glass roof requires inside cleaning as well as outside, though of course less frequently.

Artificial Illumination

Artificial lighting is required as a supplement to natural lighting when the latter is insufficient, and for interior and exterior illumination during after-dark periods of working hours in the winter. At times the excuse has been advanced that lighting is an expensive item of workshop expenses. Compared, however, with other shop charges, lighting expenditure is found to be relatively small, and therefore, considered in terms of even a modest increase in output, the fallacy is evident.

TABLE II

COEFFICIENTS OF REFLECTION OF VARIOUS SURFACES

Surface	Coefficient of Reflection per cent	Surface	Coefficient of Reflection per cent
Aluminium Paint	72	Green Light Matt	41
Black Paint Matt	6	Green Dark Matt	27
Brick Dark	22	Ivory Glossy	69
Brick Light	46	Ivory Matt	64
Buff Light Matt	36	Plaster (Cement Finish)	75
Caen Stone	72	Plaster Board	60
Concrete (Unpainted)	45	Red Carmine Matt	9
Cream Matt	62	Steel (Unpainted) Structural	16
Galvanized Iron (Unpainted)	16	Tile White Glossy	80
Glass (Ordinary)	14	White Blotting Paper	82
Grey French Matt	28	White Paint Glossy	78
Grey Dark Matt	22	White Paint Matt	77

It should be noted that light and illumination are widely different terms in the sense that light may be described as the "cause" and illumination as the "effect." Although a sufficiency of light may be provided in any given location, it does not follow that the area is correctly illuminated. Light can be grossly wasted thus losing the major part of its usefulness, but when correctly applied it is reflected or diffused and converted into illumination. The amount of light emitted by an electric lamp may run into several hundred lumens, but if it is not effectively controlled the

resulting illumination on the plane of operation may be extremely small and insufficient.

Glare. Glare may be described as "light out of place." It may be direct or reflected, that is, direct from the light source to the eye as caused by bare lamps in the line of vision, generally because the angle between the source of light and the eye is less than 30°; or reflected from an object such as a highly polished machine surface. It may be due to excessive contrast between the source and the surroundings, or it may even be due to excessive brilliancy of the source, i.e. more than 2·5 candles per square inch. Any or all of these will cause visual discomfort.

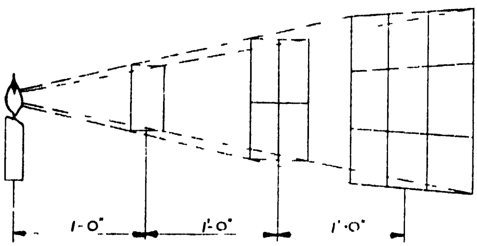


FIG. 63. THE FOOT-CANDLE

Candle-power. The term "candle-power" is used to designate the strength of the light emitted by any given source in a definite direction, and is the accepted unit of measurement. Candle-power standards are fixed by international agreement.

Horizontal candle-power (H.C.P.) is the candle-power of a lamp in the horizontal direction.

Mean horizontal candle-power (M.H.C.P.) is the average of the candle-power of a lamp in the horizontal plane.

Mean spherical candle-power (M.S.C.P.) is the average of the candle-power from a lamp in all directions.

The measuring of candle-power in any direction does not give any indication of the total amount of light emitted by a source. As an example, the beam from a searchlight may develop 2,000,000 candle-power in one direction, yet the mean spherical candle-power of the light source may only be in the region of 500.

Whilst the light emitted by a source is measured in candle-power, the intensity of illumination received at the point where the work is performed is measured in foot-candles.

The Foot-candle. The foot-candle is the intensity of illumination one foot away from a light source of one candle-power. The greater the distance light travels, the less is the illumination received per unit surface. This value can be computed by the law of inverse squares which is as follows—

$$\text{Illumination in foot-candles} = \frac{\text{C.P. (candle-power)}}{(\text{Distance from light source})^2}$$

For instance, one foot away from a light source of 16 C.P. 16 foot-candles will be obtained, while two feet away, 4 foot-candles will be the result, assuming that the light rays strike the plane of illumination at right angles (Fig. 63).

The Lumen. Light is a form of energy and it is important that the unit of energy should not be confused with the unit of intensity (candle-power). The "lumen," or unit of luminous flux, may be considered as the unit of energy in much the same way as the inch is the standard of

rainfall over a certain area, as it embodies the area illuminated by a light of definite intensity and the degree to which such area is illuminated, viz. 1 sq. ft. of surface to an intensity of 1 foot-candle. In Fig. 64 opening *OR* has an area of 1 sq. ft. and emits 1 lumen. Hence a lamp which gives 1 candle-power at a distance of 1 ft. provides an illumination of 1 foot-candle over an area of 1 sq. ft. and produces 1 lumen over that area. As such a light, giving an equal intensity in all directions, would produce a similar illumination all over the interior surface of a sphere of 1 ft. radius (2 ft. diameter), it would illuminate 12·57 sq. ft., thus producing 12·57 lumens, which is, therefore, often stated as the equivalent of 1 candle-power. This is clearly shown in Fig. 65, where an area of 1 sq. ft. is shown removed from a sphere of 1 ft. radius. Thus a lamp may be rated in the terms of the lumens it produces—

$$\text{Lumens} = \text{Foot-candles} \times \text{Area in square feet,}$$

or

$$\text{Foot-candles} = \frac{\text{Lumens}}{\text{Area in square feet}}.$$

Efficiency of Lamp. The efficiency of a lamp is measured by considering the luminous output of lumens per watt expended. It is obtained by dividing the total lumens obtained from the lamp by the input of watts. The total lumens emitted by a lamp may be ascertained by multiplying the mean spherical candle-power by $4\pi = 4 \times 3{\cdot}1416 = 12{\cdot}57$. All the light from a lamp is not effective since some of it is absorbed by the reflector and some may be absorbed by the walls and ceiling. Supposing a workshop measuring 100 ft. $\times$ 100 ft. is to be illuminated by means of 100-watt lamps on 10 ft. centres. The proposed lamp gives approximately 1200 lumens. If the reflector, ceiling, and walls absorb 33 per cent of the light, 67 per cent or 804 lumens will be effective per unit. The amount of

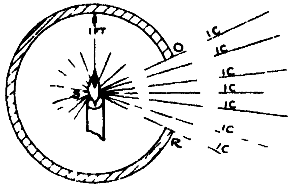


FIG. 64. OPENING *OR* HAS AN AREA OF 1 SQ FT AND EMITS ONE LUMEN

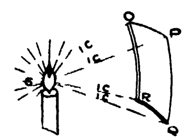


FIG. 65. ONE LUMEN FALLS ON SURFACE *OPQR*

light spread over the area, therefore, gives a resultant illumination of 8·04 foot-candles.

The Photometer. The only correct and satisfactory method of ascertaining definitely whether the lighting installation is producing maximum efficiency by giving sufficient light, is actually to measure the lighting intensity obtained in various parts of the factory or workshop. This is readily done by the use of either a visual or photo-electric type of portable illumination photometer, a small light-measuring instrument which clearly records the lighting intensity in foot-candles at any particular spot. The purchase of one of these instruments may be regarded as a good investment. By means of the photometer one is able to check periodically any reduction in lighting intensities due to depreciation, ageing of lamps, etc., and thus to take the necessary

measures in maintaining the original efficiency of the lighting installation.

Planning a Lighting Installation

There are important considerations common to many installations which must be carefully borne in mind when deciding on an installation scheme. The class of work performed, types of machine used, surroundings and architectural details, are all contributory factors to the success or failure of an installation. Each case must be treated on its merits. The following general rules should be observed—

(1) Light sources should be kept out of the direct line of vision. The eye adjusts itself to the brightness by shutting out some of the light rays, thus reducing the ability of the operator to see clearly.

(2) Flickering light sources produce eye-strain. This reduces the operator's efficiency and should be avoided.

(3) Areas should be divided symmetrically, preferably into squares, and the units evenly spaced in each square. The size of the squares depends upon architectural construction, the size of the illuminating unit used, and the mounting height available.

(4) A constant spacing ratio must be followed to secure uniform illumination. The spacing ratio is found by dividing the spacing distance by the mounting height above the plane of illumination. For example, in Fig. 70 (page 86) the spacing ratio is 1·5.

(5) One lighting unit of high intensity should not be used where several small correctly spaced ones will give better results.

(6) The installation system should be at once simple, reliable, easy to maintain, and of low operating cost.

There are four types of artificial lighting used in industrial installations—

1. *General Lighting.* This should result in producing even illumination all over the working plane, and is accomplished by the use of scientifically designed reflectors properly located as to height and spacing. Prominent among its advantages are good diffusion, absence of both direct and reflected glare, absence of dark places, and correct distribution of light on the work. Examples of good general lighting are given in Figs. 66 and 67.

2. *Localized Lighting.* This is sometimes called dropcord lighting, but without at least the assistance of general lighting it is not usually a practical proposition, owing to its high maintenance cost. A purely local lighting installation will very rarely be satisfactory, and therefore it should be avoided wherever possible. One of its disadvantages is that it is almost impossible to avoid pools of darkness and stray cast shadows.

3. *Combined General and Local Lighting.* Unless care is taken, this system carries with it the faults of the localized system. It is necessary, however, in those cases where a high intensity is required for fine work on certain machines, as this could not be economically obtained by a high intensity of general illumination. Where the majority of work carried out requires only a moderate intensity, it would not be practical to increase the general illumination greatly throughout in order to provide for a few special

Fig. 66. Night Photograph showing a Large Shop in the Shaftmoor Lane Works, Birmingham, of Messrs. J. Lucas, Ltd.
Equipped with industrial units giving a uniform lighting standard of 20 foot-candles

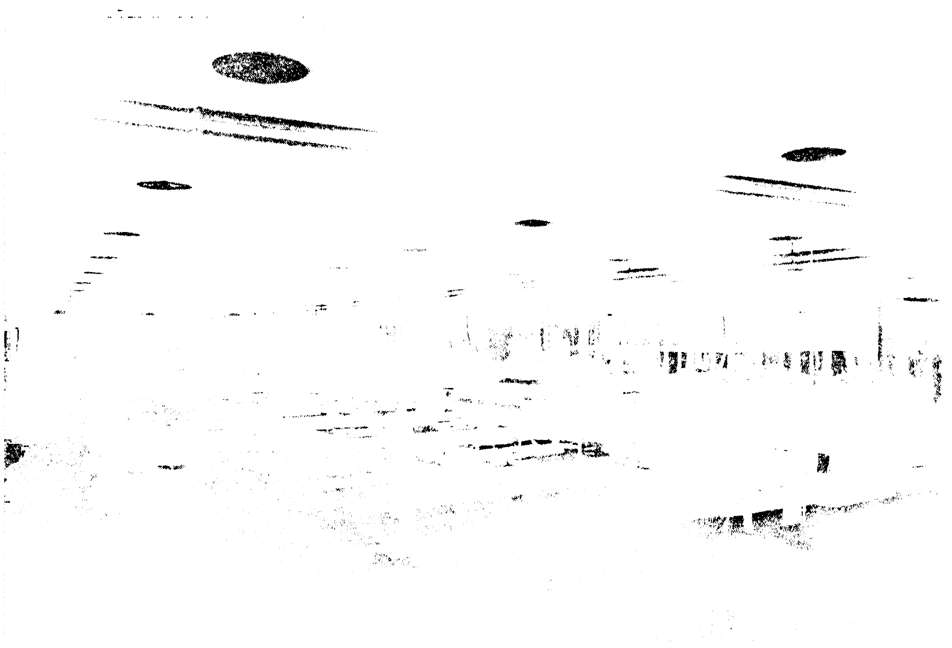


Fig. 67. Night Photograph showing a Well-lit Shop of the Birmingham Tool & Gauge Co., Ltd.

machines. In cases of this kind, the addition of high intensity local lighting as a supplement to the general lighting system would be advisable. Fig. 68 shows a night photograph of a press room where the problem was divided into two separate requirements (1) to afford general lighting to the entire working area, including the paper webs and upper structure, and (2) to provide adequate lighting upon the cylinders. It was deemed imperative to keep all lighting units away from the presses, and centre aisle lighting was therefore adopted. To meet general lighting requirements a special unit was used comprising a clear prismatic reflector and bottom refracting dish in suitable metalwork and surrounded by an opalescent cylinder. These units were mounted at a height of 13 ft. 6 in. and were equipped with 150-watt mercury discharge lamps. For the cylinder lighting, lantern units were employed with two concentrating refractor panels equipped with 80-watt H.P. mercury discharge lamps.

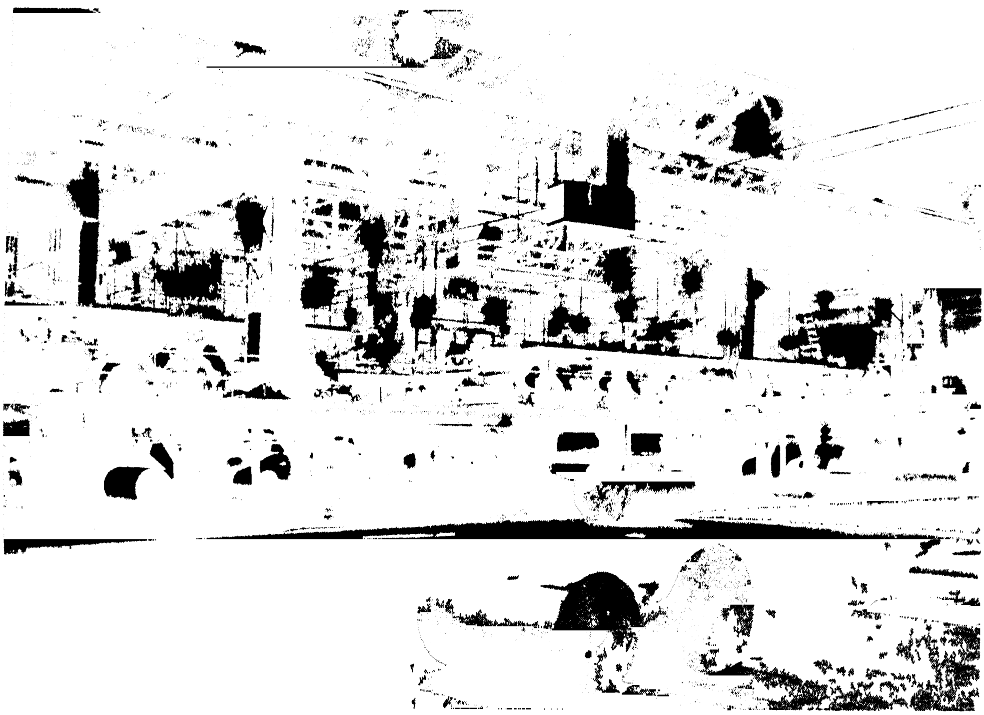


FIG. 68. NIGHT PHOTOGRAPH OF PRESS ROOM, MESSRS. WATERLOW & SONS, LTD.
(Printers of the *Radio Times* and *World Radio*)

The intensity of general illumination should always be high enough to avoid violent contrasts, the presence of which would increase the liability to accidents.

4. *Modified General Lighting.* Where

it is necessary to provide a higher intensity of illumination over some areas than at others, larger lamps and reflectors can be installed over those areas, still keeping the units at uniform spacing and height. This system has all the advantages of general lighting and none of the disadvantages of the localized, or combined general and localized systems. Sometimes, however, a supplementary directional source is needed for boring and similar operations. Adjustable bracket fittings, as illustrated in Fig. 69, are extremely useful for this purpose.

Special problems arise where explosive atmospheres, vapours or corrosive acids are present, and these must be dealt with by lighting experts only.

Location of Points

To ensure even illumination, lighting units must be arranged symmetrically and not too far apart.

Symmetry in spacing should be adhered to, and the simplest method is to divide the area to be illuminated into a number of equal-sized squares, with a unit in the centre of each, taking into consideration the position of roof girders, columns, supports, and posts, the presence of which may otherwise create unnecessary and objectionable shadows. These imaginary squares will be found to range in general practice from 10 ft. × 10 ft. to 30 ft. × 30 ft., varying, of course, in relation to the position of roof supports and posts. Architectural conditions may necessitate the division of the area into rectangles as being simpler for arranging the layout. Thus, a workshop may be automatically divided into natural bays formed by roof trusses and roof supports.

Design of Reflectors

The source of light is the "raw material" and a reflector is necessary to produce the "finished product." All

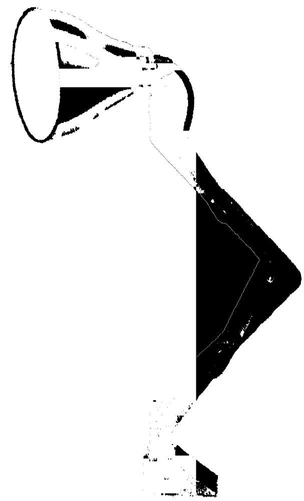


FIG. 69. ADJUSTABLE BENCH OR MACHINE LIGHT

types of lamps direct some rays upward and in other directions away from the objects to be illuminated. Relatively, these rays are not useful. The economic function of a reflector is to intercept these comparatively useless rays and distribute and direct them where they will serve a useful purpose. A correctly designed reflector will also shut off the rays coming direct to the eyes from the filament of the lamp, which would have a blinding effect if not intercepted. A lamp shaded by a properly designed reflector will throw upon the working plane the correct amount of light, whereas a lamp of higher candle-power, but

without a reflector, is a waste of potential energy. Accordingly, as far as the eye is concerned, the lamp of lower candle-power actually gives more light because of the reflector. There are three clearly defined types of reflectors—dispersive, concentrating, and angle reflectors. There is also the diffusing unit type of fitting.

Dispersive type reflectors provide a wide distribution of light. They are suitable for general overhead lighting ensuring adequate illumination on both horizontal and vertical surfaces. The reflectors should be spaced at a distance apart equal to one and a half times their mounting height above the plane of work (Fig. 70).

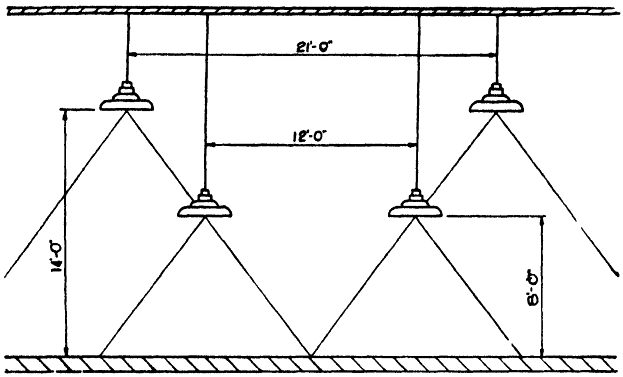


FIG. 70. SPACING RATIO OF 1·5

Concentrating type reflectors are designed chiefly for lighting shops where the mounting height must be considerable. When installed above the overhead travelling crane in large shops, they provide good illumination on the horizontal working plane. To provide uniform illumination, concentrating reflectors should be spaced a distance apart equal to their mounting height above the plane of work.

Angle type reflectors (Fig. 31, Chapter IV) are frequently employed in large works to supplement the illumination available from the overhead system, and are usually mounted on side walls or columns at a height of 15–20 ft. from the ground. Their use ensures that vertical surfaces are well lighted, and in consequence they are frequently used in large erecting shops and paint shops, where a considerable amount of the work is done on vertical surfaces.

Diffusing type fittings comprise a reflector similar to the dispersive type but with an opal glass globe. They are particularly suited to the lighting of fine assembly shops, as a high intensity of illumination is provided unaccompanied by glare from the fitting. They are also used extensively in offices and drawing offices, since they do not rely on the reflecting properties of the ceiling. Industrial diffusing units should be installed to the same spacing height ratio as dispersive reflectors.

The Photometric Curve

The photometric curve is the graphic representation of light distribution usually employed in illumination calculations. The intensity of light from a given source can be determined for various angles, these usually being in a vertical plane through the lamp axis, and the intensities obtained, expressed in terms of the candle-power, can be plotted

so as to convey clearly the manner in which the light is emitted. On the photometric curve, Fig. 71, the intensity of light given off directly downward is indicated by measuring off this intensity on the vertical to a given scale. Thus, *OA* represents the candle-power intensity directly below

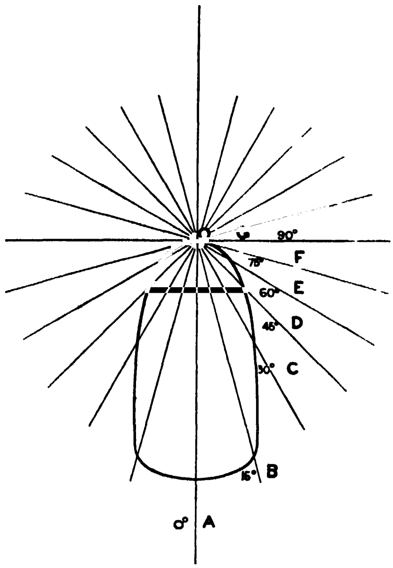


FIG. 71 DIAGRAMMATIC PHOTOMETRIC CURVE

the light. Similarly, the distances *OB*, *OC*, *OD*, *OE*, *OF*, and *OG* represent candle-power intensities given off all around the light at angles above the vertical of 15 degrees, 30 degrees, 45 degrees, 60 degrees, 75 degrees, and 90 degrees. Similarly, the candle-power intensities above 90 degrees can be measured off to the given scale along their respective angles. These points are then joined by a continuous line, *G*, *F*, *E*, *D*, etc., and this line, when completed for the 360 degrees, is called the photometric distribution curve of the light. Fig. 71 shows such a photometric curve. In practice, however, it is customary to use circular lines, as indicated in Fig. 72, to show the scale to which the candle-

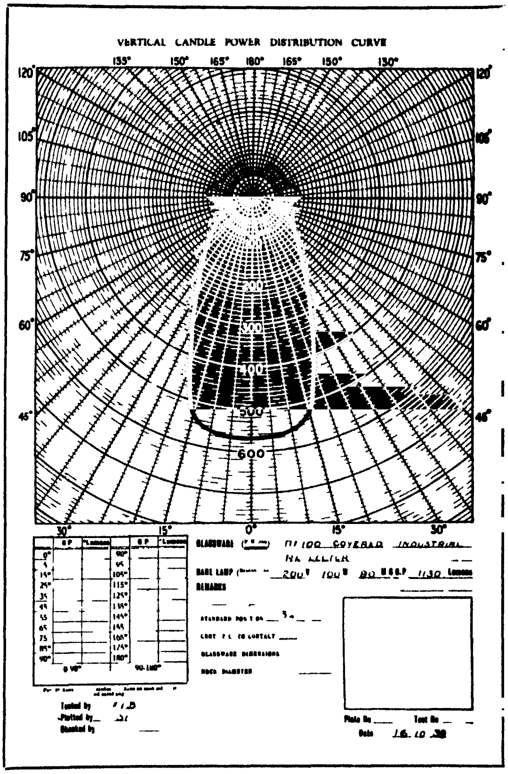


FIG. 72. REPRODUCTION OF ACTUAL PHOTOMETRIC CURVE

powers are plotted. The dotted curve gives the candle-power intensity of the lamp without the use of a reflector.

Lamp Sizes

After the position of lighting units has been settled, and the reflector selected which it is considered will best meet the conditions of the installation, the size of the lamp necessary to give

the required intensity can be determined by the following formula—

$$\text{Lamp lumens required per unit} = \text{Area in square feet per unit} \times \text{Lamp lumens required per square foot}$$

where

$$\text{Area in square feet per unit} = \frac{\text{Total floor area in square feet}}{\text{Number of units}}$$

and

$$\text{Lamp lumens required per square foot} = \frac{\text{Foot-candles} \times \text{Depreciation factor.}}{\text{Coefficient of utilization}}$$

The coefficient of utilization varies according to the type of reflector, the room proportions, and the colour of the surroundings, while the depreciation factor is the allowance made for depreciation due to accumulation of dirt and dust and deterioration of reflecting values of walls. For all practical purposes a coefficient of utilization of 0·5 can be taken as satisfactory, this figure making the necessary allowance for depreciation. Table III indicates the minimum desirable illumination intensities required to give satisfactory lighting for different industries and operations. It will be noticed that these values are considerably below daylight intensity values, which range from anything up to 10,000 foot-candles under a bright noon-day sun outside down to 100 foot-candles indoors near windows.

Type of Operation

This will decide the intensity of light required. The operations may be described as—

(*a*) Inspective, demanding a concentration of the sight at one point or small area, e.g. weaving, or

(*b*) Detective, requiring a general watch over a given process, labour only being necessary when anything goes wrong, e.g. spinning.

TABLE III

MINIMUM ILLUMINATION INTENSITIES REQUIRED

Location	Foot-candles Recommended	Location	Foot-candles Recommended
Approaches and Yards	0·25	Paint Manufacturing	10
Assembling—		Power Stations—	
Rough Work	8	Boilers	5
Fine Work	10–20	Switch-boards, Engines	8
Extra Fine Work	20 50	Printing Industry	10
Chemical Works	5	Linotype, Engraving	20–50
Clothing Factories	15	Sorting and Packing	6
Drawing Offices	15–25	Sheet Metal Works—	
Electrical Manufacturing	12	Rough Forging	6
Engraving and Die-making	20–50	Fine Forging and Welding	10
Foundry	10	Smith Shop—	
Garage and General Repairs	12	Rough Forging	6
General Offices	8	Fine Forging and Welding	10
Machine Shop—		Stone Crushing and Screening	2
Rough Work	8	Structural Steel Works	8
Fine Automatic Machines, Medium Grinding, Fine Buffing and Polishing	10 20	Warehouses	4
Grinding (fine work)	20–50	Woodworking and Cabinet-making	10

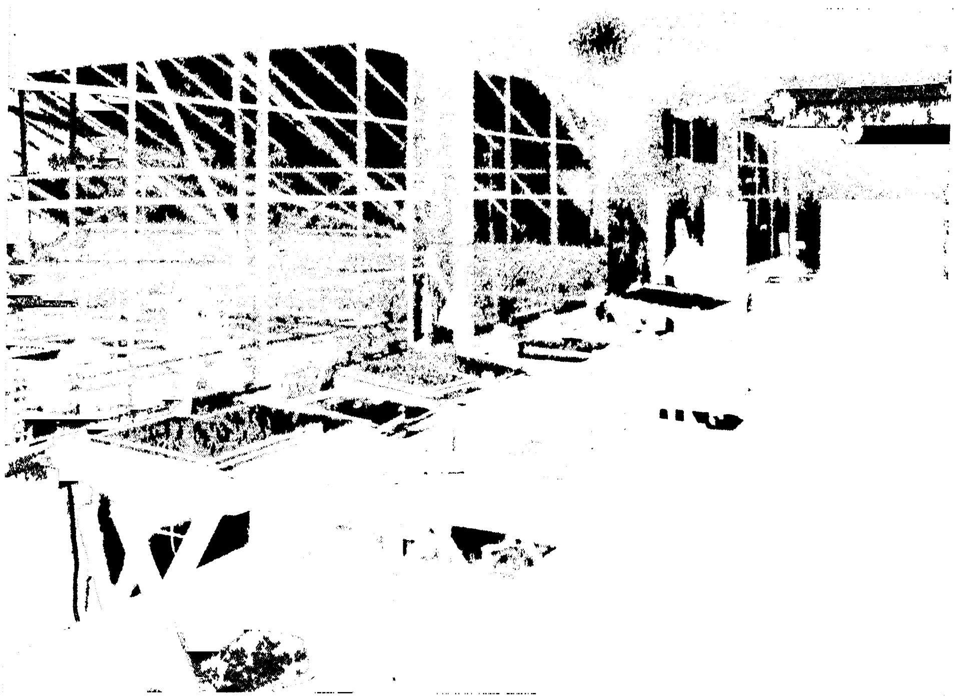


Fig 73 Technical Section of Production Planning Office
(Note also adequate proportions of shop roof light)

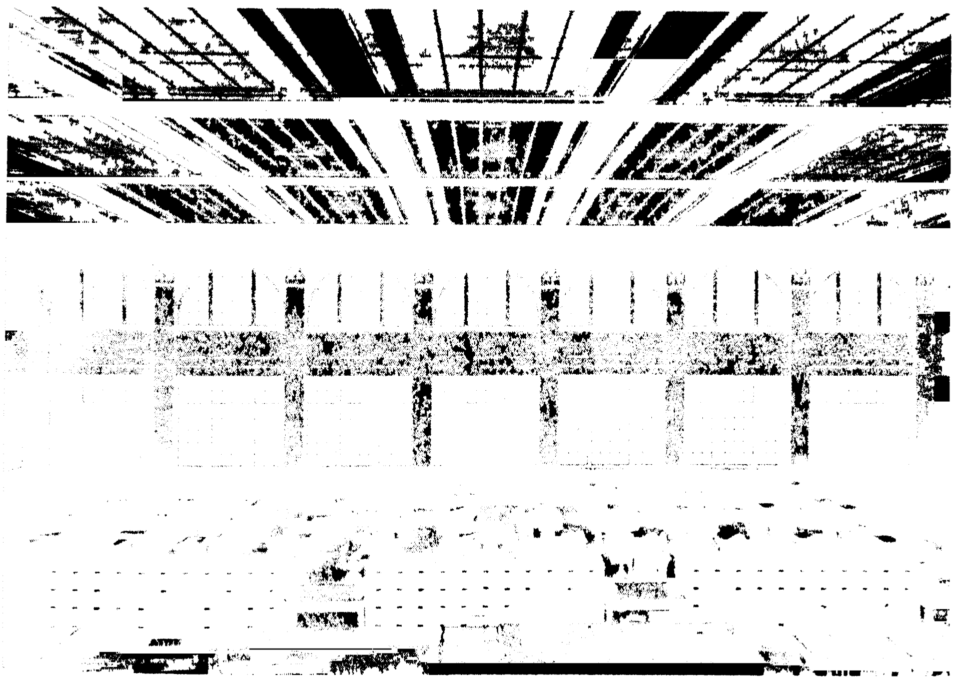


Fig 74 Office with Laylight Lighting Installation employing 200 W Industrial Reflector Units above Laylight Glazing

For inspection and the detection of defects special lighting arrangements are required.

Type of Equipment

Dark and rough surfaces absorb more light and reflect less than smooth bright ones. Machinery should be painted green or grey in preference to black. Individual motor drive to machines avoids interruption and shadows caused by belts, pulleys, and shafting.

The effectiveness of lighting is not dependent on brilliance but upon the ability of the employee to distinguish clearly and differentiate easily without eye-strain. The avoidance of irritating brilliance is as important as the elimination of partial obscurity. Several units of low intensity are far preferable to one of high intensity, so that light may proceed from several directions.

Deep shadows occasioned by the incorrect mounting or spacing of lighting units should be avoided. Their presence may cause serious accident by placing moving machinery in deep gloom.

TABLE IV
EFFICIENCY OF LIGHTING

Industry	Foot-candle Intensity with Dirty Reflector	Foot-candle Intensity with Clean Reflector	Percentage Increased Efficiency
Foundries	7	12	71
Steel Works	2	3	50
Bench Work	42·5	105	147

The frequent and systematic cleaning of all units is necessary, otherwise the efficiency of lighting falls rapidly. The comparative figures shown in Table IV, which were extracted from a Government report, prove the necessity for the regular cleaning of lamps and fittings. Dull lights are as ineffective as blunt tools, and there is a point reached where it is profitable to replace existing lamps by new ones. Cheap lamps give inconsistent performance, and increase the cost of maintenance.

Advantages of Good Lighting

Apart from the beneficial effects of good lighting upon production and in reducing the risk of accidents, working conditions are materially improved and the surroundings made more hygienic, with the result that there is less fatigue and depression amongst the employees, and in consequence they enjoy better health. Every employee does as much with his eyes as with his hands. Good light protects his eyes and guides his hands, preserves his vision and improves his skill, and also increases his confidence and promotes contentment. Good lighting is also of enormous value to the management, as it considerably aids general supervision. The psychological effect of a well-lit shop or office (Figs. 73 and 74) is considerable; it impresses all concerned—even potential customers—with a sense of orderliness and efficiency.

CHAPTER VII

MACHINE TOOLS

Definition

A MACHINE tool is a combination of the "mechanical powers," these consisting of the lever, the wheel and axle, the pulley, the inclined plane, the wedge, and the screw—the elementary contrivances of which all machines are composed. A machine tool may be hand or power operated, portable, semi-portable, or fixed. It is not, as some may imagine, a cutting tool, or other small tool, used in conjunction with a machine—it is the machine itself.

Function of Machine Tools

Machine tools are the foundation of all industrial production, inasmuch as they are the means by which all the machinery in industry is manufactured. They may be required either for the manufacture of tools, equipment, and machines, which in turn are required for the manufacture of useful products, or they may be required directly for the manufacture of useful products. The function of the machine tool is to change the shape of some material according to a predetermined plan, and this will be done either by removing a portion of it or by de-forming it. The material on which it is desired to operate will be located in the required position in the machine tool, in some cases rigidly and in others by hand. Cutting or de-forming tools attached to the machine will then operate on the material. During this operation the work may be stationary whilst the tool moves, it may move whilst the tool remains stationary, or sometimes the tool and the work may move relatively. Frequently a machine tool will be required to operate on several pieces of material simultaneously, and it may also be required to perform multiple operations.

The present age may well be called the machine age, because countless and diverse operations hitherto considered to be inseparably associated with hand operation are continually being transferred to machine tools, with a consequent reduction in labour cost. But that is not all. In a further endeavour to cheapen production costs, machine tool manufacturers pay close attention to a speedier output for a given type of machine, simplify the machine to permit of a lower rated operator, or else make it automatic in its action, thus allowing one operator to look after several machines.

Design

The progress which is made in machine tool design, in common with most branches of engineering, is very rapid. It is indeed so rapid that machine tool makers have no sooner designed and built their machines, put them through their tests, and placed them on the market—with a feeling no doubt of justifiable pride and satisfaction—than some new development

in the ingenuity of the pattern, or in the needs of the customer, requires that changes and modifications be made. In spite of this ever-present uncertainty, there can be few branches of engineering which offer greater attraction to the mechanical engineer.

Plain bush bearings have been superseded by precision type ball and roller bearings, not only for subsidiary shafts, but also for main spindles. Gearing, too, has undergone a series of step by step improvements, and to-day all gears of the best quality are hardened and ground or lapped to secure quiet running and freedom from distortion, wear, and breakage. The use of multi-splined shafts is general. Problems of inertia and momentum in starting and stopping at constantly increasing speeds have had to be faced, and the need for very accurate balance to avoid vibration, the enemy of the high-speed cutting tool, has made itself felt. The fitting of brakes for bringing spindles quickly to rest is also a necessity.

The design of beds and slides is of interest. There is the flat bed with square or dovetailed guides, and the V or inverted V form of guide, whilst some designs actually have one flat guide and the other the inverted V guide. Each type has its merits but the dovetailed slide has much to commend it, especially in such machines as planing machines, as in the event of the electrical reverse equipment suddenly failing the moving table will be prevented from overbalancing. The inverted V slide prevents any accumulation of dirt or cuttings. To reduce the wear of sliding surfaces to the minimum, the importance of providing covers to exclude cuttings, dust, and cutting fluid from the guiding surfaces will be fully recognized.

The reduction of "idle" time must always be given prior consideration, investigation showing that there is a likelihood of the machine standing for a considerable portion of its available working time. Ease of control must be carefully studied, and speed and feed changes controlled by dials or indexed levers, while quick power motions to heavy slides will greatly reduce fatigue and save time. The incorporation of pneumatic and electrically operated chucks for gripping the work speedily is desirable, whilst automatic lubrication should be regarded as a necessity on headstocks and gearboxes. The hydraulic control of machine movements is particularly suitable for grinding, shaping, and broaching machines.

Independent electric driving of machine tools is generally preferred. Some designers favour flanged motors built into the machines, others prefer texrope and silent chain drives. Feed motions and quick return motions are in many instances fitted with individual motors, and often without appreciable increase in cost, as many mechanical elements are thus avoided.

Variable Speed Pulley Drives

The extensive use of these calls for an explanation of the principles under which they operate. Variable speed pulley drives employ the principle of expanding and contracting cones forming a V-groove pulley of infinitely variable pitch diameters which, in

conjunction with a special adjustable motor base, enables driving speeds to be increased or reduced at will to the limits of the maximum and minimum pitch diameters of the pulley used, and at the same time keeping the V-ropes in the same centre line. With the motor at the nearest position to the driven shaft, the V-groove pulley assumes its largest pitch diameter, thus driving at the highest speed. At extreme centres, however, the V-groove pulley is opened out and the V-rope drives from the smallest pitch diameter, consequently at the lowest speed.

With the automatic type variable speed pulley (Fig. 75), speeds are automatically increased or reduced by rotating the handwheel on the sliding base; an alternative design called the stationary type eliminates the spring and utilizes a screwed collar which locks the cones in any required position. With the automatic type, speed adjustment is made whilst the machine is running, but with the stationary type the machine must be stopped before adjustment can be made.

Owing to the positioning of the slides, variable speed pulley drives are arranged for either right- or left-hand assembly; each complete drive can be converted on site from right-hand to left-hand assembly, or vice versa as required.

Any make and type of motor can be utilized with these drives, bases being standardized to take various sizes of motors.

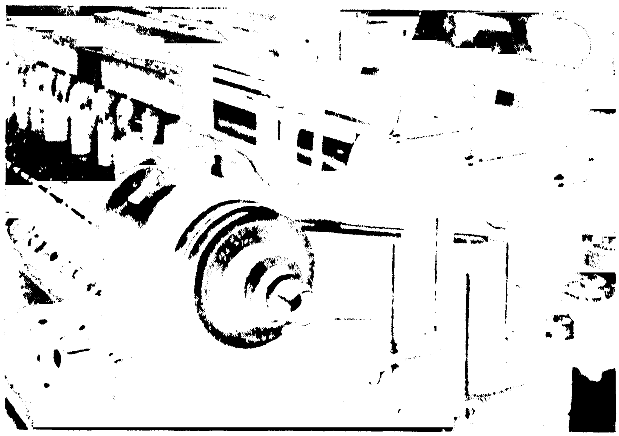


FIG. 75. AUTOMATIC VARIABLE SPEED PULLEY DRIVE

Influence of Cutting Tools

At the beginning of the twentieth century the best available material for cutting tools was carbon steel, and in those days the average speeds for machining cast iron and steel were 25 ft. per minute. The introduction of high-speed steel in 1906 caused a revolution in design, for cutting speeds of 80 ft. per minute became possible and existing machines were overtaken. Some twenty years later tungsten carbide, molybdenum titanium, and other combinations in which new metals were employed were introduced and again raised cutting speeds by successive stages to 200 ft., 400 ft., and now to 1000 ft. per minute.

It has been ascertained that the horse-power consumed by most types of machine tools increases in direct proportion to the cutting speed, and the greater power required to do justice to the constantly increasing

efficiency of cutting tools has led to the introduction of the single pulley drive, enabling the full power of the belt to be used at all speeds. The power of a machine tool required to-day may be as much as six times that required in the days of carbon steel. The use of high-speed cutting alloy tools demands not only higher speeds and greater power, but increased

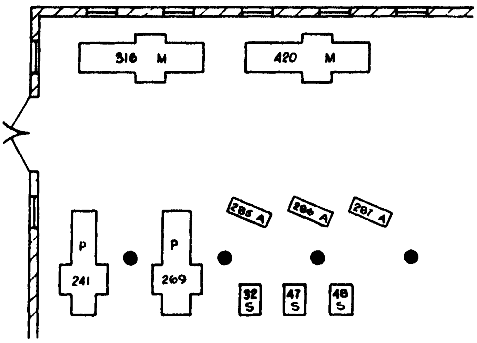


FIG. 76. BLOCK PLAN TO DEPICT MACHINE TOOL LAYOUT

rigidity as well. Hence the great increase in weight and stiffness of design of machine tools.

Layout

Reference was made in Chapter III to the two alternatives in the layout of machine tools, i.e. the group system and the production unit system. In the first, machines of a similar type are grouped together, e.g. the lathes are all placed together in one part of the shop, milling machines in another, and drilling machines in another. In the second system the machines which are necessary to deal with a component which is continually being manufactured are grouped together regardless of type, thus ensuring a flow of work in one direction only, and a minimum of transport. In some cases it will be advantageous to have a number of machines arranged on the production unit system and others on the group system. For every shop a block plan showing the base of each machine and other fixed equipment, and their registered numbers, drawn up on the lines of Fig. 76, should be arranged in large-size folio form and kept up to date. The letters shown will denote the types of machine, e.g. automatic, milling, planing, slotting, etc.

Independent Drive

There is little to commend the original form of machine battery drive, which utilizes only one motor and a line of shafting, other than that it requires a motor of considerably less horse-power than the total horse-power of the several individual motors. On the other hand it has many disadvantages. If the motor breaks down it puts a whole range of machines out of action, or if for any reason only one or two machines are required to work, the electrical energy expended remains constant just as though all the machines were working. Again, as overhead shafting is in an out-of-the-way position it may not get the attention it warrants, and under such conditions much of the energy will be wasted. Furthermore, the natural light which is absorbed by overhead shafting and its attendant belting can only be fully appreciated in those machine shops where the shafting has been removed, the improvement thus being made very noticeable.

One matter which calls for careful consideration is the question of adequate arrangements for disposing of cuttings and swarf which the high-speed machine produces at an alarming rate. Machine tool manufacturers do not always pay sufficient attention to this problem.

Coolants

There must be an adequate supply of the proper kind of coolant suitable for the particular process. Its functions will be—

(1) To keep the tool cool, thus increasing the tool life and the periods between grinding.

(2) To enable work to be turned out with good surface and finish, and conformity to precision limits.

(3) To protect the work from corrosion.

(4) To reduce the power required.

(5) To permit increased cutting speeds.

(6) To remove swarf.

If the coolant is to perform these functions efficiently it is essential that a scientifically prepared cutting fluid should be used.

Examples of Modern Machines

A number of machine tools of recent design are illustrated and their salient points briefly mentioned. The idea underlying their inclusion is to give the reader some indication of the special features of representative types of modern machines.

Semi-automatic Pattern Milling Machine. In general principle this machine (Fig. 77) consists essentially of a table having combined movements, above which an adjustable

FIG. 77. SEMI-AUTOMATIC PATTERN MILLING MACHINE

cutter spindle is carried on a powerful overhanging arm. A rising and falling motion is provided to the arm which is operated both by power motion from a built-in motor, and by handwheel. The spindle head swivels between the horizontal and vertical, and the spindle

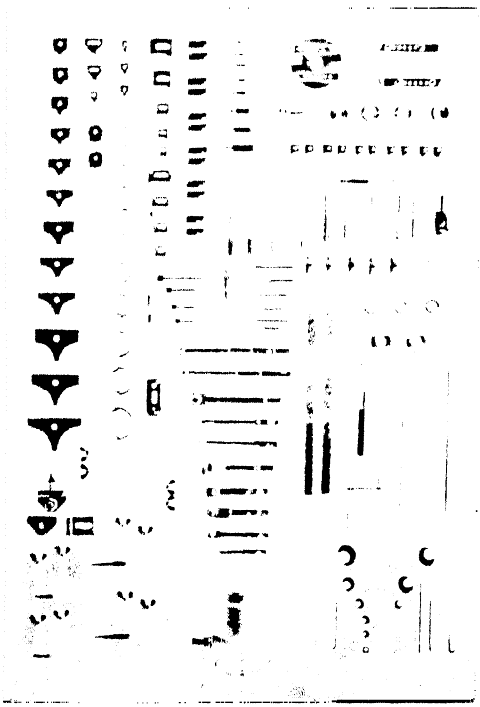


FIG. 78 STANDARD EQUIPMENT FOR SEMI-AUTOMATIC PATTERN MILLING MACHINE

has also a movement at right angles to the arm both by hand and micrometer screw to enable the cutters to be fed into the work. The spindle is mounted on heavy ball bearings and is driven by spiral gears with ground teeth, which are totally enclosed and run in grease. A feature of this drive is that it allows the spindle to be dropped below the level of the arm to enter a corebox with its axis parallel to the face of the work. A further advantage is that the spindle can be adjusted to any angular position, which saves re-setting the work and materially increases the application of the cutters. Not the least desirable feature of the drive is that the cutters are carried close up to the spindle bearings, which not only ensures steady running and consequently cleaner and more accurate cutting, but eliminates the need for long boring bars.

Power is taken from a ball bearing shaft within the arm, the rear end of the shaft being driven by a four-speed motor mounted directly on the shaft. Alternative speeds are therefore made available for any class of work and the spindle is reversible at each speed. The motors for both the main spindle and the rise and fall of the arm are controlled by a single lever on a control station mounted on the end of the arm. Starting, reversing, and stopping, also the rise and fall for the arm, are all obtained by the one lever. Speed change is obtained by selector switch mounted together with main contactor panel, which is housed in the main column of the machine. All other movements of the machine are mechanically controlled and the flexibility of movement obtained allows the machine to operate conveniently and with accuracy on either geometric or irregular patterns or coreboxes. Index scales and automatic stop devices are embodied on practically all movements, making the machine simple to operate and easy to manipulate by the average pattern-maker.

Although to a very large extent the mechanical movements of the machine govern its efficiency, its capacity on both pattern and corebox work is undoubtedly largely attributable to the comprehensive range of tools, tool holders, and attachments which form the standard equipment. These are shown in Fig. 78. It is sound policy to obtain a complete range of tools whenever a machine is purchased.

Multi-burner Oxy-acetylene Cutting Machine. The multi-burner cutting machine illustrated in Fig. 79 is capable of making six cuts simultaneously. The machine, which has a cutting area for each burner of 30 in. × 10 in., has a built-up frame consisting of a bedplate with two work supports attached. The bedplate carries two pedestals on which are mounted two pairs of coupled hinged frames. The frames are coupled not only at the front extremities and the centre joints, but also adjacent to the back pivots at the extremities of a second pair of extended arms. By this method of suspension short link frames can be used, and consequently a minimum of ground space is required.

The front coupling bar carries the six cutting burners mounted so that each burner can be independently adjusted, vertically, longitudinally or transversely. These adjustments are by rack-and-pinion and lead screw, so that each burner can be quickly and accurately set. The horizontal slides are of V formation with ample adjustment for wear.

The burners are of a patent remote control type with Bowden operation of heating and cutting oxygen valves. A unit control is provided giving simultaneous operations for all burners. The control has three positions, i.e. off, heating, and cutting.

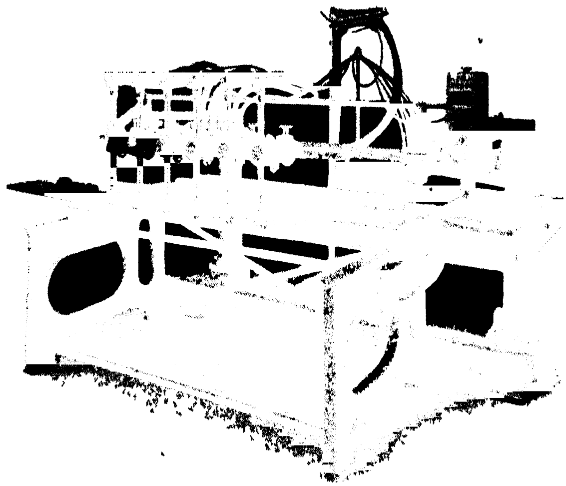


FIG. 79. MULTI-BURNER OXY-ACETYLENE CUTTING MACHINE

The oxygen is supplied to the burners through a six-way distribution manifold, and each burner hose can be instantly uncoupled from a self-closing coupling. The combustible gas is fed through a six-way tank distributor and each outlet is provided with a gas cock.

The right-hand extremity of the front coupling bar carries an electrically driven universal tracer head with starting, stopping, and reversing switches and oxygen control lever. With the universal electric tracer the machine can be operated from a

drawing or blue print, from a wooden or soft metal templet cut to exact size, or automatically from a channel or strip aluminium templet. In addition straight lines and circles are cut automatically. The drawing or templet table is mounted on a bracket attached to one of the work supports and is arranged to turn over. One side is of aluminium for drawings, and the other of wood for templet-fixing. A swinging tube support is provided to carry the oxygen tubes, gas tubes, and electric cable, and prevents the possibility of these fouling the framework of the machine.

Capstan Lathe. This lathe (Fig. 80) is a single-pulley or individually motor-driven high-speed machine, equally suitable for either chuck work or production from bars up to 1½ in. diameter.

The headstock is of a type allowing fast speed-changing through friction clutches which run in oil. Six spindle speeds in each direction are instantly available, these speeds being arranged in three groups so that two forward and two reverse speeds are obtainable without the necessity of moving gears. The three speed groups are suitable for a wide range of work, the low set covering steel or cast-iron work, the medium set such work as may be called for on gun-metal castings, and the high range for small bar work or high-speed drilling in aluminium and allied materials. The required range is obtained by the partial rotation of a lever on the front of the headstock which operates sliding gears.

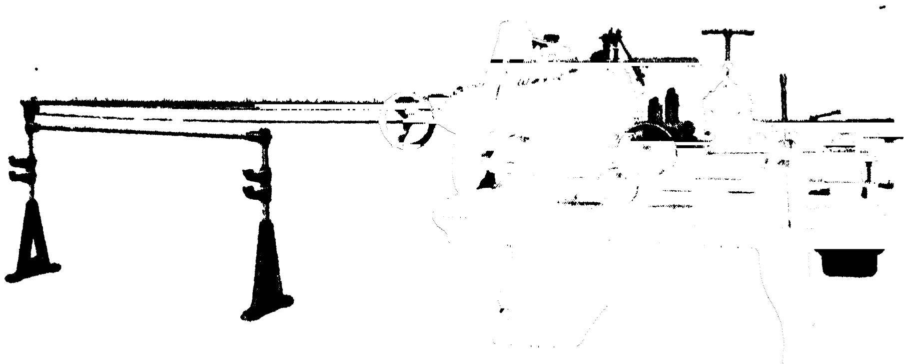


FIG. 80. CAPSTAN LATHE WITH INDIVIDUAL MOTOR DRIVE

A patented automatic brake motion is incorporated with both clutch operating levers. This brake is of the internal expanding type, both segments being lined with bonded asbestos, and is automatically cam operated, so that from any speed the spindle is brought to rest almost instantaneously by the simple action of moving either clutch lever to its central position. The action of reversing the spindle also applies the brake automatically, and thus relieves the reverse clutches of all strain. The spindle is mounted on combined ball journal and thrust

bearings together with heavy duty roller bearings, and all rotating parts of the headstock are also carried on ball or roller journals. Automatic pump lubrication is provided to all bearings including the spindle, and to all gears. The sliding saddle and cross slide are of rigid construction, and both motions are obtained by handwheels. The longitudinal motion is through rack and pinion, and five stops are provided which can be used in either direction. The cross slide is actuated through a square thread screw and nut, and dead stops are provided in each direction. An indicator dial of large diameter is also fitted.

The capstan rest can be clamped to the bed in any desired position. The slide has wide and accurately fitted bearings and is provided with adjustable taper strips to take up wear. The slide is actuated by a star wheel through a pinion and rack. The normal stroke of the top slide when using the automatic revolve motion is 10 in. by rack and star handle, but if the turret is rotated by hand a useful stroke of 13 in. is obtainable. The automatic feed to the capstan slide has six rates, three of the changes being provided by the rotary motion of a lever on a small gearbox at the left-hand end of the bed, these being doubled by a "push-pull" arrangement situated on the apron for the capstan rest. The normal range of these feeds is from 60 to 400 spindle revolutions per inch of traverse. The feed can be engaged and disengaged by hand as required, and stops are provided on the capstan slide which automatically disengage the feed when the predetermined slide movement is completed.

FIG. 81. COMBINATION TURRET LATHE (MEDIUM SIZE)

Combination Turret Lathe (*Medium Size*). This lathe (Fig. 81) has been designed to meet the demand for a rigid, high-speed machine allowing the maximum use of tungsten carbide cutting tools. The single-pulley all-geared headstock is a powerful unit, with the spindle mounted on roller journal and combined journal and ball thrust bearings of large diameter. Eight spindle speeds are obtainable in either direction. The speed of the driving pulley can be altered to give different speed ranges. All speed changes are obtainable by sliding gears mounted on solid six-spline

shafts. Gear changes cannot be made until the driving clutch is disengaged and, as every lever withdraws the clutch and applies a brake before the gears can be moved, speed changes are effected under "no-load" conditions. The spindle and all gears and shafts are lubricated automatically by means of a pump, and as the lower gears revolve in oil, both positive and splash lubrication are obtained irrespective of spindle speed. Sight dials are provided to check the oil level and the pump outlet.

The overhead pilot bar is bridged across the headstock, and is clamped at both ends. The spindle is ground all over its external diameters, the flanged nose being 7·500 in. plus 0·000 to minus 0·0002 in. in diameter to which chucks and faceplates are directly attached by studs. The saddle has automatic sliding, surfacing, and screw-cutting motions. The sliding and surfacing feeds are operated by the same lever, and it is impossible to engage both simultaneously as opposite motions of the lever are required. The cross slide is of high tensile steel, with a square turret giving four tool positions, and an adjustable two-way rear toolpost. Eight stop positions are provided for the surfacing feeds (four in each direction) and six stops, mounted on a shaft which can be rotated, provide for tripping the longitudinal motions of the saddle. The cross slide screw is fitted with a large micrometer dial and the handwheel for the sliding motion carries an accurate indicator of large diameter. A swinging cover protects the cross slide from dirt and swarf.

The gearbox is driven from the end of the spindle by a train of wheels enclosed within the bed, and provides motion to two independent feed shafts and the leader screw. Variations in speed are obtainable through the levers at the left-hand end, which operate sliding spline shafts through gears and thus provide three changes to the lead screw, ten changes to the sliding and surfacing feed shaft, and five changes to the turret feed shaft. A convenient change on the turret saddle increases the gearbox changes so that ten feeds to all motions can be obtained. The screw-cutting motion is applied to the saddle and is obtained by means of a detachable leader screw and nut, the leader being driven from the gearbox, which allows the rotation to be altered as required in the ratio of equals, 2 or 4 to 1 with the spindle. By this means it is possible to cut three different pitches with each leader. The turret saddle is of rigid construction and slides directly upon the bed, giving a longitudinal travel of 34 in. There are ten rates of automatic feed, a lever on the saddle itself actuating an auxiliary gearbox in the apron which gives two feeds in a ratio of approximately five to one and doubles the five feeds obtainable through the main gearbox.

The bed is a semi-steel casting with a nickel chrome content which gives a hard, close-grained wearing surface. The bed covers are made from heavy channel sections of stainless steel and are fixed to the bed, cored passages of similar shape being provided through each saddle so that both may be moved quite freely without

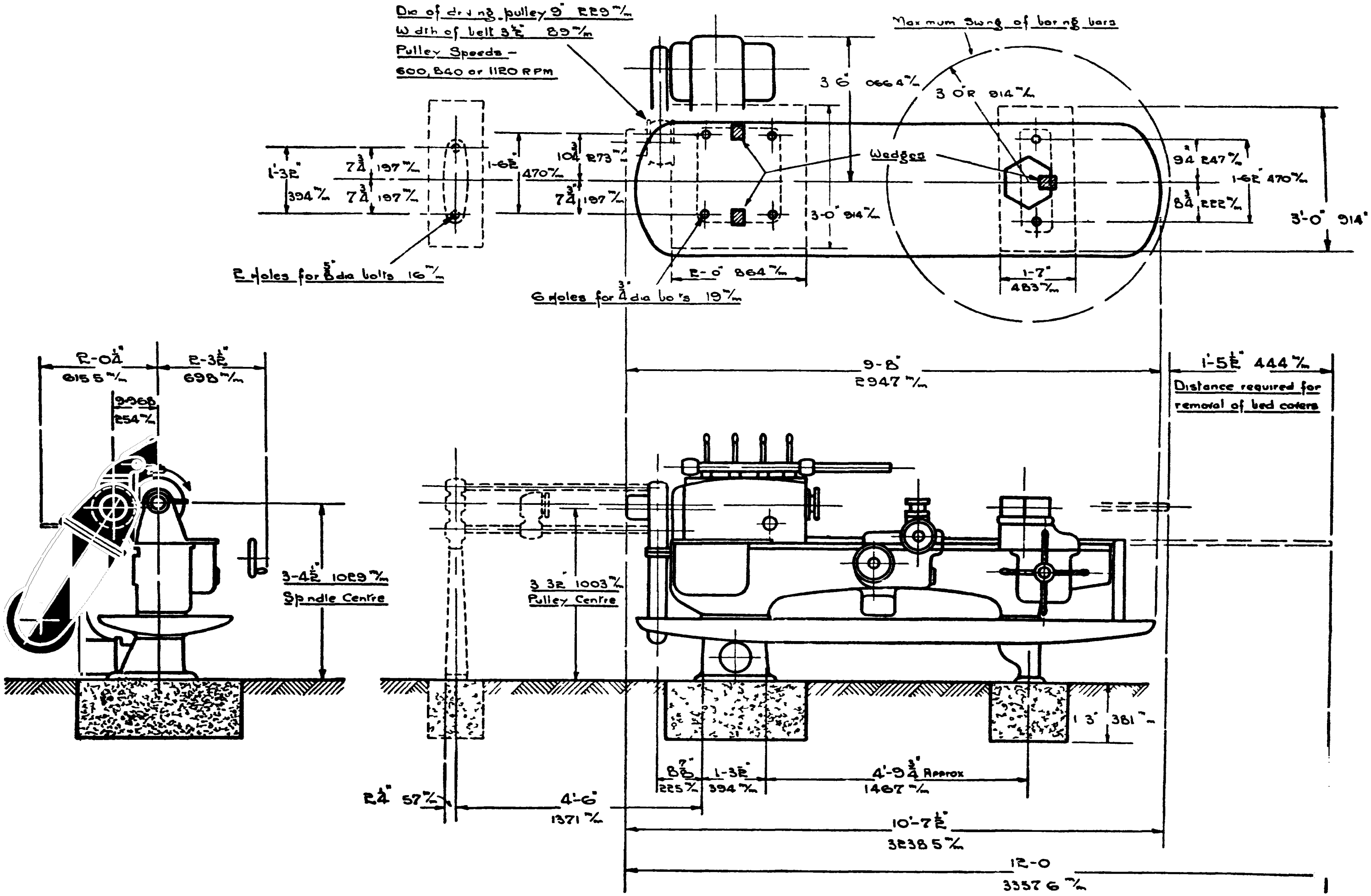


Fig 82 Foundation Plan for Combination Turret Lathe

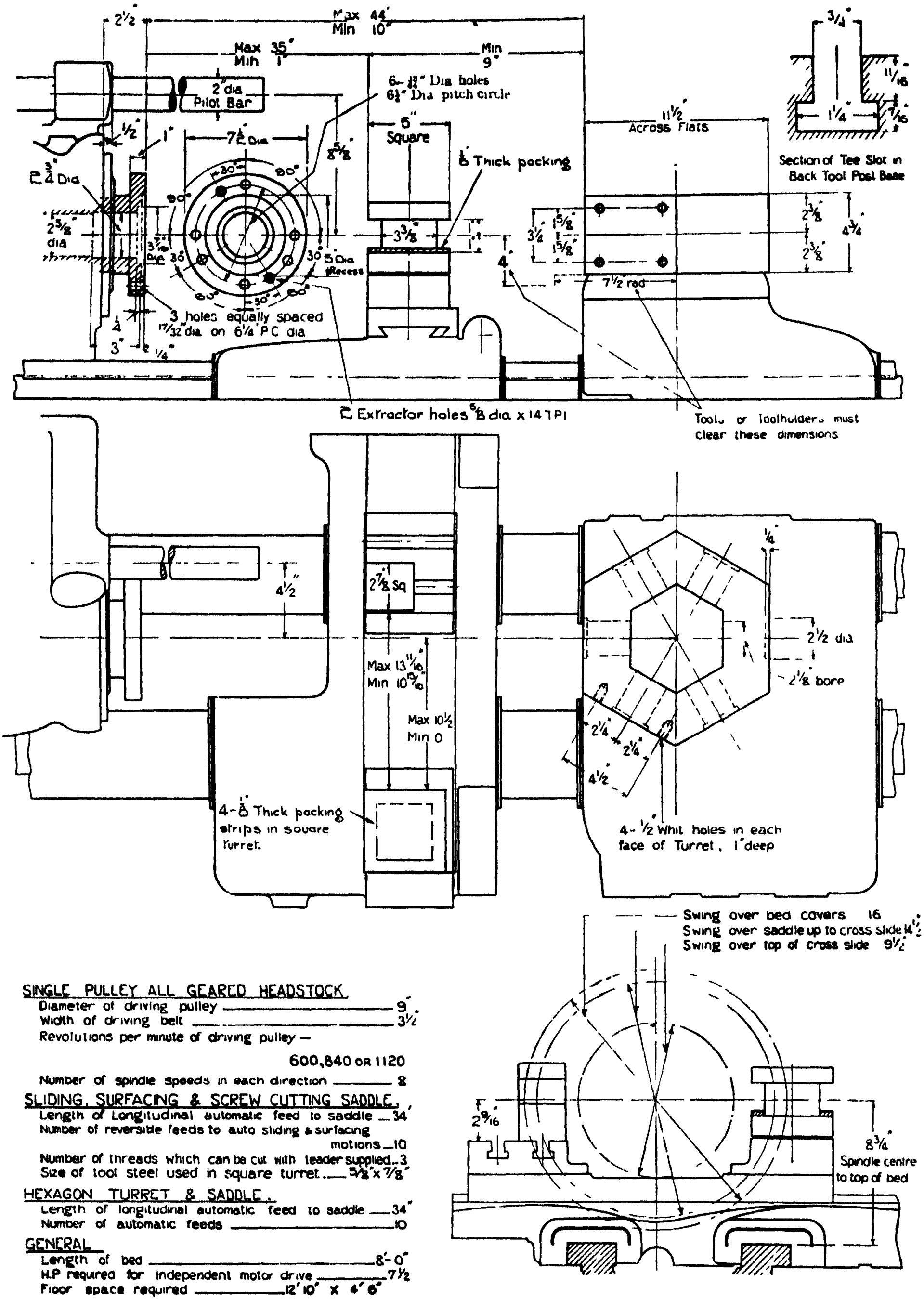


FIG. 83. CAPACITY CHART FOR COMBINATION TURRET LATHE

interference from the covers. Automatic lubrication of the moving parts is secured by the use of four plunger pumps, one each in the headstock, feed gearbox, intermediate saddle apron, and turret saddle apron.

Fig 82 shows the foundation plan for this machine, such a plan usually being necessary when any new machine is installed. It is customary for the manufacturer to provide one. Fig. 83 is the capacity chart for the same machine. A chart of this type is invaluable in connection with production planning and one should be prepared for every machine installed.

Combination Turret Lathe (Large Size). This powerful lathe (Fig. 84) has been designed with a view to the requirements of both the high speed and heavy cutting which tungsten carbide and modern alloy tools will allow. The single-pulley all-geared headstock gives sixteen speeds in each direction, and as all gear shafts and spindles are mounted on ball and roller bearings an extremely high factor of efficiency is obtained at the cutting point. The spindle has a flanged nose 16 in. in diameter to which chucks are directly attached, thus reducing overhang to a minimum. The saddle has automatic sliding, surfacing, and screw-cutting motions. The sliding and surfacing feeds are operated by the same lever and, as with the previous machine, it is impossible to engage both simultaneously due to opposite motions of the lever being required.

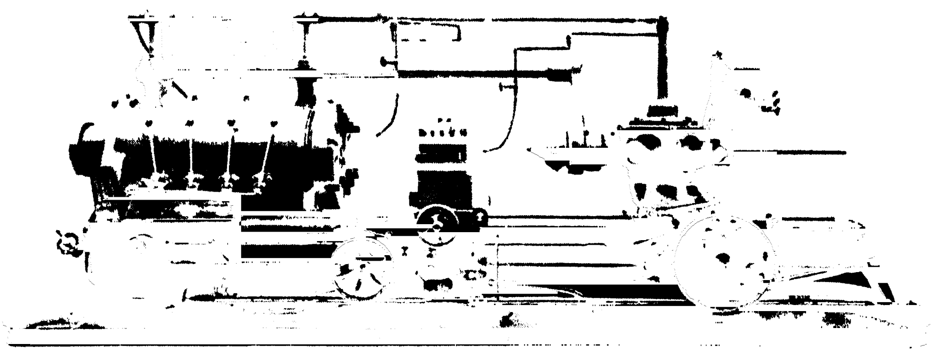


FIG 84 COMBINATION TURRET LATHE (LARGE SIZE)

Rapid power traverse motions are fitted for the cross-slide and longitudinal movements of the saddle. Automatic lubrication by pump is provided to all moving parts of the saddle and apron, including the saddle bearing on the lathe bed. The cross slide is of high-tensile steel and a square turret and rear toolpost are supplied as part of the standard equipment.

Eight stop positions are provided for the surfacing feeds (four in each direction) and six stops mounted on

a rotary shaft provide for tripping the longitudinal motions of the saddle. The chasing saddle apron forms a gearbox through which sixteen changes of feed to the saddle are provided. With the three changes obtainable from the gearbox, three groups of sixteen changes are available to the sliding and surfacing motions, i.e. forty-eight rates of feed in each direction. The feed gearbox is driven by a train of wheels (enclosed within the bed) from the end of the spindle, and provides motion to a feed shaft and the leader screw. A reversing motion is fitted so that right- and left-hand screws can be cut from the leader.

Screw-cutting motion is applied to the saddle and is obtained by means of a detachable leader screw and nut, the leader being driven from the gearbox, which allows the rotation to be altered as required in the ratio of equals, 2 or 4 to 1. By this means it is possible to cut three different pitches with each leader. For instance with a four-thread screw, either four, eight or sixteen threads per inch can be cut, whilst the direction of rotation of the lead screw can be instantaneously reversed by means of a lever on the gearbox, so that both right- and left-hand threads can be produced with any leader.

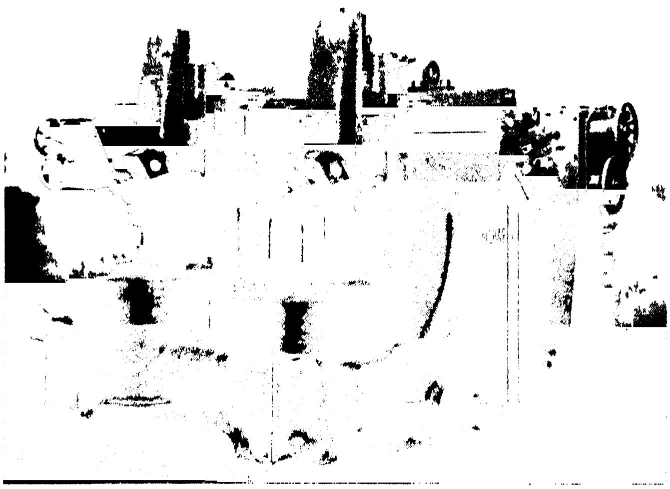


FIG. 85 DUPLEX VERTICAL BORING AND TURNING MILLS

Quick power traverse in both directions is fitted to the intermediate saddle and cross slide. These movements allow the cutting tools carried by these units to be brought quickly and easily into close proximity to the component in the chuck. The turret saddle is of rigid construction and slides directly on the bed. The bed, the width of which is 26 in., is a semi-steel casting with a nickel chrome content which gives a hard, close-grained wearing surface. A flat top automatically lubricated from each saddle provides a rigid bearing, and cross ribs of the semi-lattice girder type contribute to an immensely strong construction, with provision for swarf clearance through triangular holes of large dimensions. A large tray is provided for cuttings and coolant. The narrow guide principle eliminates the tendency to cross-wind and ensures ease of hand movement.

Duplex Vertical Boring and Turning Mills. All controls on this machine (Fig. 85) are centralized within easy reach of the operator when in the working position. The actual number of control levers has been reduced to a minimum, a special feature in this connection being the "joy-stick" control to the rapid power traverse. The turret slide is balanced by counterweight and can be swivelled for taper boring and turning, the swivel slide being fitted with accurate indexing mechanism. Automatic feeds are provided in the vertical, horizontal, and angular directions, and these can be changed or reversed instantly. Setting blocks are provided for locating the turret central with the table. This feature in no way interferes with the traverse of the turret when required to go beyond the centre. The turret is a nickel chrome casting having six faces bored to receive bars and, when required, drilled and tapped to take the toolholders. It is a substantial unit and is released, rotated, indexed, and relocked by a single lever.

The table is of the four-jaw independent or three-jaw self-centring and independent chuck type. The left-hand table on the duplex machine is provided with reversing motion when required. The table is driven by large-diameter steel spur gear and double-housed pinion. This form of drive obviates any tendency of the table lifting when taking heavy cuts. The gearbox incorporates a multi-disc clutch, and the transmission therefrom is through bevel wheels to sliding gears and on to further bevels to the table pinion. All gears are of chrome nickel steel, heat-treated and ground. All speed changes are made through sliding gears, completely eliminating dog clutches. Ball or roller bearings are fitted throughout the transmission.

Inspection covers are fitted for convenience in adjusting the clutch and for general examination purposes. Twelve speeds are provided to the table, ranging from 6 to 120 r.p.m., the higher speeds enabling full advantage to be taken of carbide cutting tools. Speed changes are made through two levers on the front of the base, and starting and stopping are effected by a lever adjacent to the speed change levers, the latter also operating an effective brake. The gearing is interlocked, and changes cannot be made until the clutch is disengaged. Eight rates of feed are provided vertically, horizontally, and angularly, ranging from 0·006 in. to 0·243 in. The feed box containing the sliding feed gears also houses the friction clutches for the rapid power motion. The high-speed shafts run in roller or ball bearings.

Rapid power traverse is obtainable in all directions, the feed being automatically disengaged before the rapid traverse can be engaged. "Joy-stick" control is provided to the rapid power traverse motion by means of which the direction of movement of the slide corresponds with that of the lever. Fine hand adjustment is manipulated through handwheels, and index dials enable adjustments of 0·001 in. to be made. The slides are of the narrow guide type. Automatic lubrication is supplied to the main bearings and

driving gears, and bath lubrication is supplied to feed and rapid traverse boxes.

Radial Drilling Machine. This machine (Fig. 86) will drill holes up to 2 in. diameter. The swing of the arm describes a circle of 12 ft. diameter. The spindle slide is of compact form mounted on the arm, upon which it

FIG. 86 RADIAL DRILLING MACHINE

has rapid hand traverse on rollers, through handwheel, pinion, and steel chain, the latter having adjustment to maintain correct tension. The correct weight distribution and the mounting of the motor, in conjunction with the disposition of the armways, assist in this facility of movement. Locking of the spindle slide on the arm and locking of the arm on the pillar are both effected by one lever. Operating motions are centralized on the spindle slide and therefore speed and feed changes, stopping, starting, and reversing of spindle, raising and lowering arm, moving and locking spindle slide, can be effected without the operator leaving his working position.

The pillar or column for carrying the arm is of strong cylindrical section, and is accurately ground on the bearing portion upon which the arm is fitted and moves. The arm carrying the spindle slide is of a very strong section, well ribbed and braced, to ensure maximum resistance against lifting and twisting stresses. It has well-extended bearings upon the large-diameter pillar which, with the special arrangement of rollers, ensures easy radial movement. The arm-elevating motion is obtained from an independent motor carrying worm reduction gear running in an oil bath, mounted as a complete unit at the top of the pillar. The arm and spindle slide are locked by the operation of a single lever.

By the operation of an independent lever conveniently placed on the pillar portion of the arm, the latter can be locked against radial adjustment only, leaving it free for elevating and lowering without loss of position radially. By bringing the drill into contact with the work by means of the quick hand traverse, and exerting a slight pressure on the handwheel operating this traverse at the moment of contact, the self-acting feed is automatically engaged. A range of twelve speeds, varying between 70 and 2000 r.p.m., is obtainable by the movement of a lever in a convenient position on the spindle slide, operating through sliding gears of high-grade alloy steel with ground teeth, and mounted upon short solid splined shafts running in

ball bearings. The final drive on to the spindle is through worm gear. Six rates of spindle feed are available, obtained by a movement of one lever.

The feed change gear is housed in the same box as the speed change gearing, and the whole of the gears are arranged to run in an oil bath. A patent device provides for the appearance of speed and feed readings at one central position. To select the correct speed and feed the operator moves the speed-change lever until the size of hole to be drilled is indicated against the division showing the material which is being used. The feed lever is then moved until the appropriate feed is shown through the aperture, when the following details will be shown by the indicator—

(1) Size of drill in use.
(2) Drill feed in cuts per inch
(3) Speed of drill in r.p.m.
(4) Class of material being drilled.
(5) Cutting speed of drill.

A sensitive lever feed is incorporated which enables the spindle to be fed down by hand to the limit of its traverse. The spindle is of solid six-splined form in the driving part. It is accurately ground (including the splines and internal Morse taper) and is of special high-grade alloy steel, heat-treated, with the nose treated to a high Brinell hardness to ensure durability and maintenance of accuracy under the constant insertion and removing of drills and sockets. The final drive to the spindle is through worm gearing which is ball bearing mounted and working continuously in an oil bath.

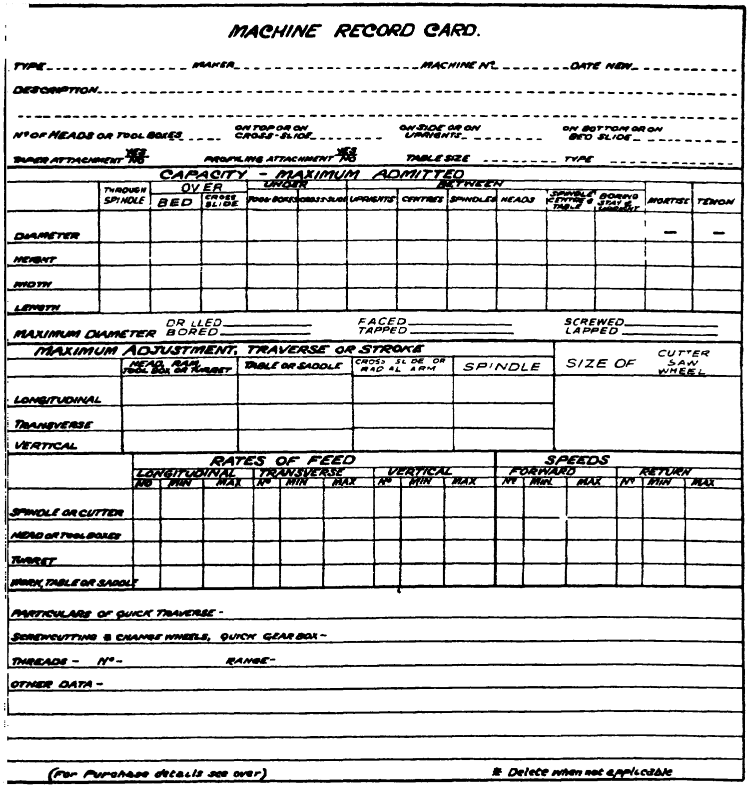
The drive is by means of a standard horizontal foot-mounted motor of constant speed located at the back of the spindle slide. The baseplate is of strong construction and specially ribbed to withstand lifting and twisting strains. The main ribs and underside of the plate are return beaded at the bottom. Spur driving gears are hardened and profile ground with bores broached to fit spline-ground shafts, the latter being made from special quality heat-treated steel. Ball bearings are provided on all gear and driving shafts, also on other parts of the machine where they can be advantageously included. Main driving gears run continuously in an oil bath and lubrication of arm slideways and pillar bearings is effected through nipples to which a grease gun or oil gun is applied. The total weight of the machine is a little over two tons.

Machine Tool Record Cards

A universal machine capacity card of the type shown in Fig. 87 should be prepared and kept in the production planning office for every machine tool which is installed in the factory. Such a card will prove invaluable. Another card, the machinery and plant record card (Fig. 88), will require to be kept by the works accountant to enable him to apportion correctly the workshop expenses for the particular machine.

Justification of Purchase

Before a new machine can be purchased certain preliminary steps are of course necessary, and in view of the outstanding importance of these various steps it is proposed to devote the


MACHINE RECORD CARD.
TYPE .... MAKER .... MACHINE Nº .... DATE NEW ....
DESCRIPTION ....
Nº OF HEADS OR TOOL BOXES .... ON TOP OR ON CROSS-SLIDE .... ON SIDE OR ON UPRIGHTS .... ON BOTTOM OR ON BED SLIDE ....
TAPER ATTACHMENT YES/NO PROFILING ATTACHMENT YES/NO TABLE SIZE .... TYPE ....

CAPACITY - MAXIMUM ADMITTED	THROUGH SPINDLE	OVER BED	OVER CROSS SLIDE	UNDER TOOL BOXES	UNDER CROSS SLIDE	BETWEEN UPRIGHTS	BETWEEN CENTRES	BETWEEN SPINDLES	BETWEEN HEADS	BETWEEN SPINDLE CENTRE & TABLE	BETWEEN BORING STAY & UPRIGHT	MORTISE	TENON
DIAMETER												—	—
HEIGHT													
WIDTH													
LENGTH													

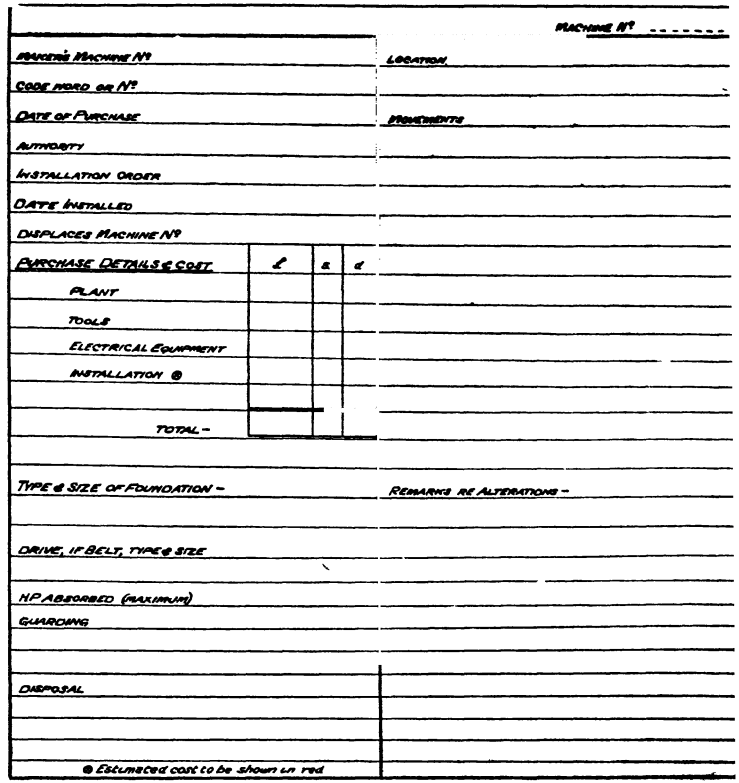
MAXIMUM DIAMETER DRILLED ____ BORED ____ FACED ____ TAPPED ____ SCREWED ____ LAPPED ____

MAXIMUM ADJUSTMENT, TRAVERSE OR STROKE	HEAD, RAM, TOOL BOX, OR TURRET	TABLE OR SADDLE	CROSS SLIDE OR RADIAL ARM	SPINDLE	SIZE OF CUTTER SAW WHEEL
LONGITUDINAL					
TRANSVERSE					
VERTICAL					

	RATES OF FEED LONGITUDINAL Nº	MIN	MAX	TRANSVERSE Nº	MIN	MAX	VERTICAL Nº	MIN	MAX	SPEEDS FORWARD Nº	MIN	MAX	RETURN Nº	MIN	MAX
SPINDLE OR CUTTER															
HEAD OR TOOL BOXES															
TURRET															
WORK TABLE OR SADDLE															

PARTICULARS OF QUICK TRAVERSE -
SCREWCUTTING & CHANGE WHEELS, QUICK GEAR BOX -
THREADS - Nº -   RANGE -
OTHER DATA -
(For Purchase details see over)   * Delete when not applicable

(*front*)


MACHINE Nº ....
MAKER'S MACHINE Nº   LOCATION
CODE WORD OR Nº
DATE OF PURCHASE   MOVEMENTS
AUTHORITY
INSTALLATION ORDER
DATE INSTALLED
DISPLACES MACHINE Nº

PURCHASE DETAILS & COST	£	s	d
PLANT			
TOOLS			
ELECTRICAL EQUIPMENT			
INSTALLATION ●			
TOTAL -			

TYPE & SIZE OF FOUNDATION -   REMARKS RE ALTERATIONS -
DRIVE, IF BELT, TYPE & SIZE
HP ABSORBED (MAXIMUM)
GUARDING
DISPOSAL
● Estimated cost to be shown in red

(*back*)

FIG. 87. MACHINE CAPACITY CARD

remainder of this chapter to their explanation. At the outset it should be made clear that the mere fact of a new design of machine tool coming on to the market is not in itself sufficient justification for displacing a similar but older type which is capable of further service. As in all problems associated with engineering and industry generally, it is entirely a question of £ s. d. It must be ascertained whether the installation of the new machine will show a satisfactory monetary saving on the present cost of

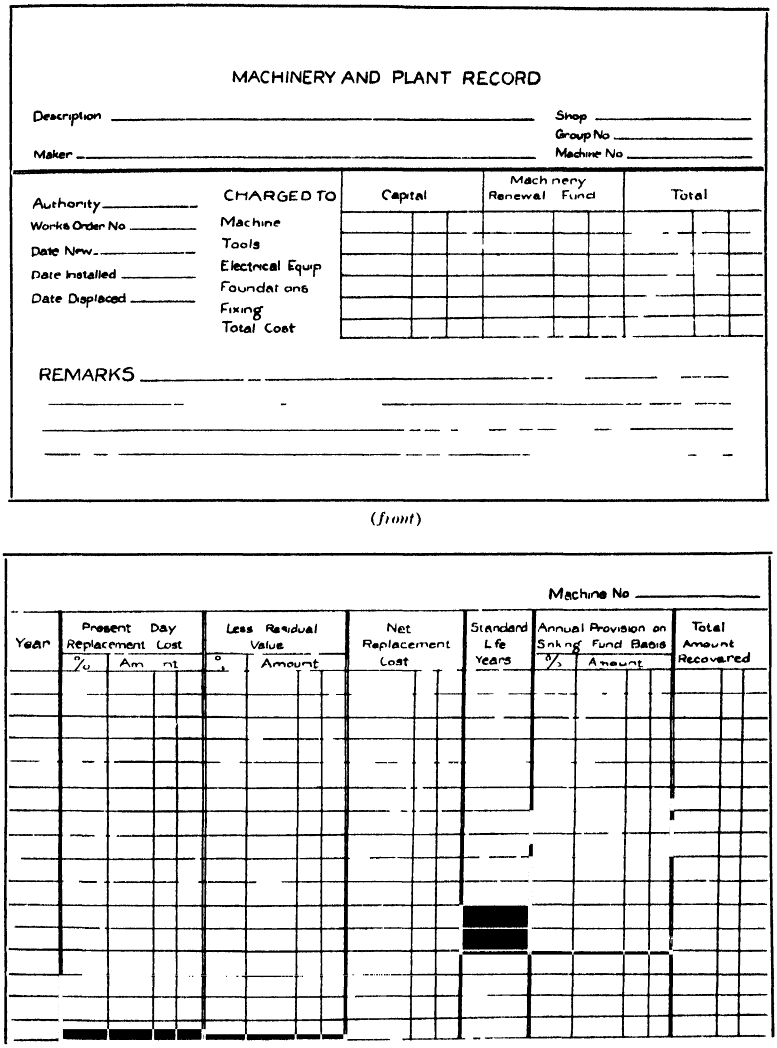


FIG. 88. MACHINERY AND PLANT RECORD CARD

production. The only way to prove this is for the plant and machinery assistant to prepare a financial statement showing the existing and the proposed conditions.

For example, assume that in a certain machine shop there are four old planing machines operated full-time by four machinists, two of whom are rated at 40s. and the other two at 42s., but all earning an average of 35 per cent bonus per 47-hour week. The practical knowledge and experience of the plant and machinery assistant will reveal that the performance of a modern planing machine, with an operator rated at 42s., will give an output at least equal to two of the old machines. Hence he will prepare and send out to one or more of the leading machine tool makers who have specialized in planing machines, an inquiry inviting them to tender for two new machines which will take the place of the four machines already installed. This inquiry may read as follows—

3rd July, 1940

Dear Sirs,

Two Tandem Table Planing Machines

We contemplate purchasing two tandem table planing machines in accordance with the specification given below. Our Conditions of Contract are sent herewith, and we shall be obliged if you will kindly submit your quotation so as to arrive not later than 25th July.

TWO— High-speed Electrically Driven Planing Machines, with spiral drive table, electrical feed motion and solenoid operating lifting tool boxes. Two tool boxes on cross rail and one on each upright. The machines to be fitted with tandem work tables, each table to be 8 ft. long. Width between housings to be 3 ft. Height under cross rail to be 3 ft. Primary drive motor and starter to be suitable for 440 volts, 3-phase, 50 cycles.

We also send herewith questionnaire forms and specification for the A.C. and D.C. equipment, which should be completed and returned with your quotation.

A general arrangement drawing, together with a detailed specification, should accompany your quotation.

Your price should include delivery charges to the above address.

Please state the source of origin of materials, together with the best delivery date you can offer.

Yours faithfully,
For Turnbull, Winfield & Co., Ltd.
(Signed) S. M. Bates

The plant and machinery assistant will compare and contrast the various replies received and will tentatively decide from which firm he proposes to make the purchase. This will enable him to draw up a financial statement on the lines indicated in Fig. 89, a brief explanation of which is given below.

Column A. These amounts must show the labour costs under the present conditions and the proposed conditions. Piecework prices, in conjunction with quantities anticipated, can often be used in place of annual earnings.

Column B. The amounts to be shown here will be a certain percentage of those included in Column A. The actual percentage figure to be used will be furnished by the works accountant. Generally it should be revised annually, as it should be based on the actual compensation paid in a year plus the firm's portion of the National Insurance over the same period.

Proposed Scheme—
To displace four old planing machines and install two modern planing machines which will give the same output (makers' guarantee) and will require only two operators instead of four.

Particulars of Plant to be Displaced by the Introduction of New Equipment

Reg. No. of Machine	Description	Maker	Date New	Cost when New	Estimated Present-day Cost
				£	£
36	6-ft. Planing Machine	Strutt	1914	200	600
37	6-ft. Planing Machine	Green	1916	205	600
84	12-ft. Planing Machine	Daykin	1920	330	740
88	12-ft. Planing Machine	Hunt	1924	345	740
	Present-day Cost				2680
	Present-day Cost of Fixing				80
	Estimated Cost of Removing				20
	GROSS TOTAL				2780
	Less Estimated Residual Value of Plant				30
	TOTAL NET COST (G)				2750

Particulars of Plant to be Purchased—

Description: Two Planing Machines.
Maker: May & Company.

	£
Cost of Plant	3400
Cost of Electrical Equipment	125
Cost of Fixing New Plant	100
GROSS TOTAL (H)	3625
Less Estimated Residual Value	25
TOTAL NET COST (J)	3600

Labour Costs

Present Conditions	Proposed Conditions	Anticipated Saving
		£
Two Metal Machinists rated at 40s. per 47-hour week. Plus 35 per cent premium bonus. Plus 15s. cost-of-living bonus. × 50 weeks = £345		345
Two Metal Machinists rated at 42s. per 47-hour week. Plus 35 per cent premium bonus. Plus 15s. cost-of-living bonus × 50 weeks = £358	Two Metal Machinists rated at 42s. per 47-hour week. Plus 35 per cent premium bonus. Plus 15s. cost-of-living bonus. × 50 weeks = £358	

Operating Costs

	Wages Cost per annum	Workmen's Compensation and National Insurance at 6 per cent of Wage Cost	Interest on Items (G) and (H) at 4 per cent per annum	Repairs at 8 per cent for (G) and 5 per cent for (J) per annum	Renewals at 3 per cent of Items (G) and (J) (20 years)	Total Cost per annum
	(A)	(B)	(C)	(D)	(E)	(F)
	£	£	£	£	£	£
Present Conditions	703	42	110	220	102	1177
Proposed Conditions	358	22	145	180	134	839
Increase (Proposed Conditions)	—	—	35	—	32	67
Decrease (Proposed Conditions)	345	20	—	40	—	405
				NET DECREASE		338

Decrease expressed as a Percentage of the Total Cost per annum under Present Conditions— $\frac{338}{1177} \times 100 = 28{\cdot}7$ per cent

(*N.B.* As the decrease is in excess of 10 per cent the proposed scheme may be considered to be financially sound.)

FIG. 89. FINANCIAL CONSIDERATIONS FOR PURCHASE OF NEW EQUIPMENT

Explanatory Notes

In this example the calculations are based on the principle that provision is made for renewals at costs prevailing at the time the new equipment is purchased.

The application of 4 per cent interest on £2750 (see Column C) must not be taken literally. The result arrived at is the increased loss of potential interest-earning capital. Another way of explaining the figures given in Column C is as shown below—

	£
Amount required for renewals	3625
Amount provided for renewals	2750
Actual extra expenditure or loss of interest-earning capital	875
4 per cent	35

Column C. In the disbursement of the two sums of money denoted by (G) and (H) the question of interest, which otherwise would have been obtained, must be taken into consideration. Simple interest, therefore, possibly at 4 per cent, should be allowed.

Column D. Provision must be made for repairs, and figures will be available based on past experience. Some firms will prefer to use the same percentage figure for both old and new equipment; others will prefer to vary the percentage according to the specific case which they have under consideration.

Column E. These amounts will be arrived at by referring to the Sinking Fund, Table V. Assuming the life of all the planing machines to be twenty years, as shown in Table VII, it will be seen that £0·037216 will become £1 at the end of twenty years, if invested at 3 per cent compound interest. Hence in the case of amount (G) the amount considered to have been put away annually will be 2750 × £0·037216 = £102. Similarly in the case of amount (J) the amount to be put away annually will be 3600 × £0·037216 = £134. In practice this latter amount will be chargeable to

TABLE V

SINKING FUND AT 3 PER CENT

Amount to be Set Aside Annually to provide £1 at the End of a Selected Period

No. of Years	Amount	No. of Years	Amount
	£		£
1	1·000000	26	·025938
2	·492611	27	·024564
3	·323530	28	·023293
4	·239027	29	·022115
5	·188355	30	·021019
6	·154598	31	·019999
7	·130506	32	·019047
8	·112456	33	·018156
9	·098434	34	·017322
10	·087231	35	·016539
11	·078077	36	·015804
12	·070462	37	·015112
13	·064030	38	·014459
14	·058526	39	·013844
15	·053767	40	·013262
16	·049611	41	·012712
17	·045953	42	·012192
18	·042709	43	·011698
19	·039814	44	·011230
20	·037216	45	·010785
21	·034872	46	·010363
22	·032747	47	·009961
23	·030814	48	·009578
24	·029047	49	·009213
25	·027428	50	·008866

TABLE VI

COMPOUND INTEREST AT 3 PER CENT

Amount of £1 per Annum immediately after each Annual Payment is Made

No. of Years	Amount	No. of Years	Amount
	£		£
1	1·00000	26	38·55304
2	2·03000	27	40·70963
3	3·09090	28	42·93092
4	4·18363	29	45·21885
5	5·30914	30	47·57542
6	6·46841	31	50·00268
7	7·66246	32	52·50276
8	8·89234	33	55·07784
9	10·15911	34	57·73018
10	11·46388	35	60·46208
11	12·80780	36	63·27594
12	14·19203	37	66·17422
13	15·61779	38	69·15945
14	17·08632	39	72·23423
15	18·59891	40	75·40126
16	20·15688	41	78·66330
17	21·76159	42	82·02320
18	23·41444	43	85·48389
19	25·11687	44	89·04841
20	26·87037	45	92·71986
21	28·67649	46	96·50146
22	30·53678	47	100·39650
23	32·45288	48	104·40840
24	34·42647	49	108·54065
25	36·45926	50	112·79687

workshop expenses, and in the latter case will involve a sum of £5 8s. being debited to the shop concerned every four-weekly period for each of the two new planing machines. Whilst strict unanimity can scarcely be expected, Table VII may be taken as representative of good average practice. Tables VI and VIII are included for the purpose of throwing more light on this intensely interesting aspect of machinery renewals.

Column F. The totals shown will enable the increased or decreased working costs to be ascertained. In the example given the decreased expenditure on the total cost per annum under present conditions equals 28·7 per cent.

Where it is proposed to change the

TABLE VII

ANTICIPATED LIFE OF MACHINE TOOLS

Class of Machine	Estimated Life	Class of Machine	Estimated Life
	Years		Years
Air Compressors (Fixed)	20	Hydraulic Presses	30
Air Compressors (Portable), Electric or Petrol	7	Levelling Blocks	50
Annealing Furnaces	25	Mobile Cranes	15
Automatic Machines	15	Multi-spindle Drilling Machines	20
Band Sawing Machines (Wood)	20	Oil Engines	25
Bar Reeling Machines	20	Oil Extractors and Separators	25
Blowers and Fans	20	Oxy-acetylene Cutting Machines	15
Boilers, Multi-tubular and Water Tube, and Mechanical Stoker	20	Overhead Track Equipment	25
Boring, Drilling, and Milling Machines	20	Paint Grinding Mills	20
Broaching Machines	20	Petrol Trucks and Tractors	7
Capstan Lathes	20	Planing Machines	20
Case-hardening Furnaces	20	Plano Milling Machines	25
Circular Sawing Machines	20	Plate Bending Machines	25
Coke Crushing Machines	20	Plate Straightening Machines	25
Concrete Mixers	8	Pneumatic Drills (Portable)	7
Core Making Machines	25	Pneumatic Hammers (Fixed)	25
Die Casting Machines	15	Pneumatic Hammers (Portable)	7
Drilling and Tapping Machines—Horizontal and Vertical	20	Pneumatic Moulding Machines	20
Drop Stamps	20	Precision Grinding Machines	15
Electric Cranes (all types for use in Sheds, Yards, Docks, etc.)	30	Pulley Blocks	40
Electric Drills (Portable)	10	Radial Drilling Machines	20
Electric Motors	25	Sand Riddles	10
Electric Welding Machines	8	Sand Blasting Machines	20
Fly Presses	30	Sanding Machines, etc. (Portable)	10
Forging Machines	20	Sawdust Conveyers	25
Furnaces (Ordinary)	30	Steam Hammers	25
Gas Engines	25	Stone Crushers	25
Grindstones	20	Tinsmiths' Folding Machines	20
Hack Sawing Machines	15	Vices	20
Heating Apparatus for Shops	25	Wall Jib Cranes	40
Hydraulic Accumulators	30	Water Feed Pumps	20
Hydraulic Mains	40	Water Distilling Plant	20
		Water Reservoirs	40
		Weighing and Testing Machines	25
		Weighing Machines—Truck and Platform	40
		Woodworking Machines	20

TABLE VIII

APPROXIMATE PROPORTION OF REPLACEMENT COST PROVIDED AT EXPIRATION OF EACH YEAR OF LIFE

(On Sinking Fund Basis with Interest at 3 per cent)

Expired Life Years	Estimated Total Life – Years 5	6	7	8	9	10	15	20	25	30	35	40	45	50
1	·2	·2	·1	·1	·1	·1	·1	·0	·0	·0	·0	·0	·0	·0
2	·4	·3	·3	·2	·2	·2	·1	·1	·1	·0	·0	·0	·0	·0
3	·6	·5	·4	·3	·3	·3	·2	·1	·1	·1	·1	·0	·0	·0
4	·8	·6	·5	·5	·4	·4	·2	·2	·1	·1	·1	·1	·0	·0
5	1·0	·8	·7	·6	·5	·5	·3	·2	·1	·1	·1	·1	·1	·0
6		1·0	·8	·7	·6	·6	·3	·2	·2	·1	·1	·1	·1	·1
7			1·0	·9	·8	·7	·4	·3	·2	·2	·1	·1	·1	·1
8				1·0	·9	·8	·5	·3	·2	·2	·1	·1	·1	·1
9					1·0	·9	·5	·4	·3	·2	·2	·1	·1	·1
10						1·0	·6	·4	·3	·2	·2	·2	·1	·1
11							·7	·5	·4	·3	·2	·2	·1	·1
12							·8	·5	·4	·3	·2	·2	·2	·1
13							·8	·6	·4	·3	·3	·2	·2	·1
14							·9	·6	·5	·4	·3	·2	·2	·2
15							1·0	·7	·5	·4	·3	·2	·2	·2
16								·8	·6	·4	·3	·3	·2	·2
17								·8	·6	·5	·4	·3	·2	·2
18								·9	·6	·5	·4	·3	·3	·2
19								·9	·7	·5	·4	·3	·3	·2
20								1·0	·7	·6	·4	·4	·3	·2
21									·8	·6	·5	·4	·3	·3
22									·8	·6	·5	·4	·3	·3
23									·9	·7	·5	·4	·4	·3
24									·9	·7	·6	·5	·4	·3
25									1·0	·8	·6	·5	·4	·3
26										·8	·6	·5	·4	·3
27										·9	·7	·5	·4	·4
28										·9	·7	·6	·5	·4
29										1·0	·7	·6	·5	·4
30										1·0	·8	·6	·5	·4
31											·8	·7	·5	·4
32											·9	·7	·6	·5
33											·9	·7	·6	·5
34											1·0	·8	·6	·5
35											1·0	·8	·7	·5
36												·8	·7	·6
37												·9	·7	·6
38												·9	·7	·6
39												1·0	·8	·6
40												1·0	·8	·7
41													·8	·7
42													·9	·7
43													·9	·8
44													1·0	·8
45													1·0	·8
46														·9
47														·9
48														·9
49														1·0
50														1·0

Authority for New Plant

NEW PLANT
Date ordered
Delivery date
Date received
Account % passed
% passed
Date Plant set to work
Shop
Machine No.

OLD PLANT
Date removed
How disposed o

Fig 90 Record of Purchase of Plant

19

REPORT OF FAILURE OF MACHINERY

Shop No Machine No
Description of Machine
Makers
Time of Breakdown
Nature of Breakdown
Estimated Time for Repairs
Shop Concerned for Repairs
Disposal of Staff

Remarks

Foreman

Fig 91 Repairs to Machinery Form

Fig 92. Turning Section of Machine Shop

FIG 93 MILLING SECTION OF MACHINE SHOP

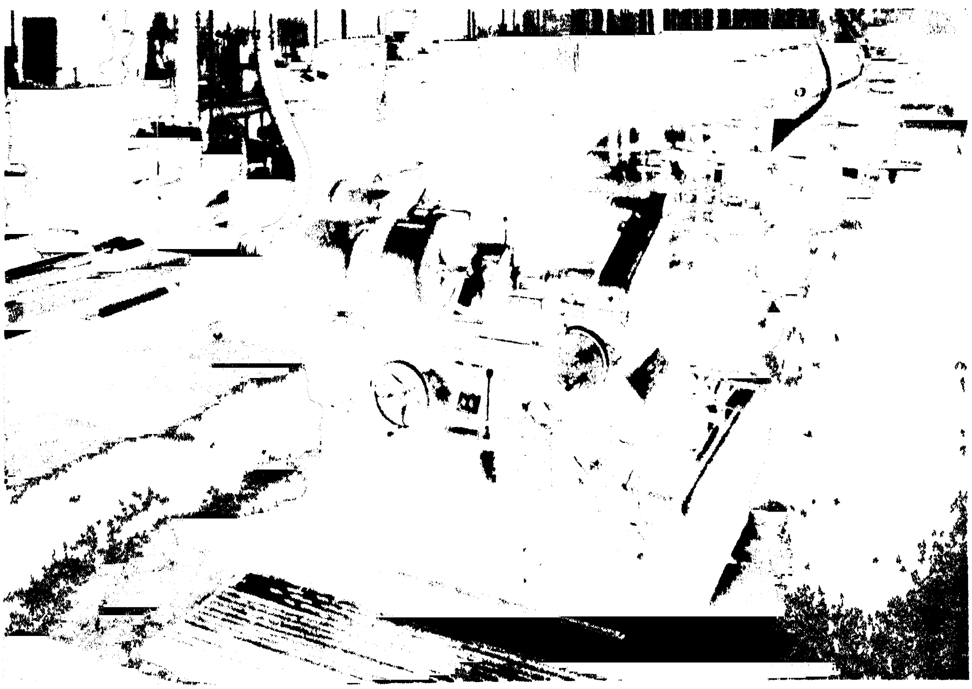


FIG 94. GRINDING SECTION OF MACHINE SHOP

method of manufacture it may be necessary to consider the raw material costs as well as the direct labour charges. For further information on this point the reader should refer to Chapter XXI.

As soon as a scheme is sanctioned it should be recorded in the manner shown in Fig. 90, and a copy of the form attached to the relevant correspondence.

Repair Costs

Whenever repairs of machines and fixed plant are required, authority should be obtained for the work to be put in hand as per Fig. 91. On receipt of this form from the shop concerned the works manager will, if satisfied that the expense to be incurred is justified, issue a factory order to cover the ordering of material and authorizing the work. If the anticipated expenditure does not involve more than a nominal sum, say £1, the special factory order may not be deemed necessary. In all instances of breakdown, however, a register should be maintained to show what each machine is costing, this record being invaluable when considering new or altered equipment.

It should, of course, always be borne in mind that well-organized shops, on the lines of those illustrated in Figs. 92, 93, and 94, will experience a minimum of trouble due to breakdowns.

CHAPTER VIII

THE TOOL ROOM

In the general efficiency of the tool room largely lies the successful manufacture and price-fixing of almost every engineering product. If tools or gauges are badly designed or badly maintained, or if the wrong type of tool is used, increased working costs, a resultant higher price, and a less satisfactory article are inevitable. It is therefore recommended that the maximum ingenuity and foresight should be brought to bear on all tool room activities. There is no phase of the organization, particularly if it embraces jig and fixture design and manufacture, which is capable of showing a greater return for the money expended. The work, too, is equally fascinating for the designer and the tool-maker.

Large firms will usually find it preferable to design and manufacture most of their own tools and gauges. Small firms will generally purchase standard types of tools, but will prefer to design and manufacture those which are peculiar to their own line of business.

There are some who advocate that the control of the tool room should be vested in the machine shop superintendent, whilst others consider it to be a more satisfactory arrangement for no section to be given preferential treatment in the supply of tools but for the tool room to be self-contained and separately controlled. Consequently it would be unwise to lay down a hard and fast rule, a good deal depending on the nature of the product and the size of the factory. It is certain, however, that if most of the machining is carried out under one authority it will be the wiser plan for that authority to have complete control over all the tool and gauge making. Fig. 95 is illustrative of important sections of the tool room, the layout and equipping of which latter must always be most carefully considered.

Cutting Tools

There are many proprietary brands of cutting tool on the market, but whether they be of high-speed tool steel or tungsten carbide, only experience will reveal which is the best type to be used for a given class of work. Suitable machine tools are essential if good results are to be obtained with tungsten carbide cutting tools and tips, and it will be useful to summarize the desirable characteristics.

(1) The machine in use must be reasonably rigid and free from lift or movement of spindle and slides.

(2) There must be as little vibration as possible at the speed and with the cuts desired.

(3) There must be ample power in the drive without any danger of slipping either in clutch or belt.

(4) The tool must have rigid support near the tip, allowing only sufficient room for swarf clearance.

(5) The drive should be positive so that there is no fluctuation in speed.

(6) Centres and chucks must be in good condition and positive in action. Even on first-class machine tools the strictest attention to all details is necessary. A live or rotating tool stock centre is usually advisable, and any wear on the bearings of such a centre can cause frequent failure of the tools. Although chucking details may be adequate at ordinary speeds, they may be useless at increased speeds, and small alterations in this direction can either cause failure or they can improve performance by as much as 30 per cent.

Generally, with carbide tools, a light cut and a fine feed combined with a high speed will give better results and a better finish than will a lower speed with a heavier cut and feed, removing perhaps an equivalent amount of material per minute.

It should be noted that if a machine is taxed to the limit of its power when using high-speed steel tools, there is little to be gained by using the more expensive carbide tools, except where the material is not machinable with high-speed steel. From this it will be deduced that the use of carbide tools is not recommended on low-powered, obsolete, or worn machines.

FIG 95 TOOL ROOM LAYOUT

Brazing of Carbide Tips

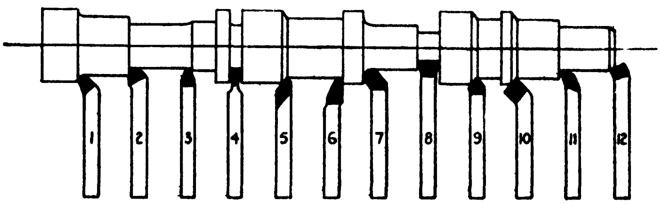
It is essential that the brazing of tungsten carbide tools should be carried out in temperature-controlled furnaces, those which are generally employed for hardening high-speed steel being well adapted for the purpose. Cleanliness must be observed during the brazing operations, as if the shank, tip, furnace, or tools are dirty, satisfactory brazing cannot be performed. If a preheating furnace is not available, it is possible to braze the tools in a high-temperature furnace only, but care must be taken to prevent the carbide tip being subjected to rapid changes of temperature.

Owing to the low shear strength of all tungsten carbide alloys, it is important that very keen edges, such as are obtained by burnishing or lapping, are finally produced on the tools if the best results are to be obtained. A keen edge will reduce the pressure on the tool and the heat generated at the point, with a considerable increase in tool life.

The design of carbide tools with a complicated form should be avoided as the cost of their production is very heavy and an accidental breakage involves disproportionate loss. It should not be overlooked, however, that there are many highly successful applications of profiling tools and "button" tools. Fig. 96 illustrates diagrammatically the more usual types of cutting tool.

Front Clearance Angle and Top Rake

Fig. 97 illustrates the meaning of these two terms. Once the clearance and top rake angles on the tool have been decided upon, subject to experience with the particular material being cut, they should be rigidly observed. The clearance angles should always be as small as is permissible.



1 Cranked Round Nose Turning and Facing Tool
2 Cranked Light Turning and Facing Tool
3 Round Nose Turning and Facing Tool
4 Parting and Grooving Tool
5 Straight Tool for Chamfering and Heavy duty Turning
6 Side Cutting or Knife Tool
7 Light Turning and Facing Tool
8 Plain Turning and Recessing Tool
9 Light Turning and Facing Tool
10 Cranked Knife Tool for Heavy duty Turning
11 Cornering or Recessing Tool
*12 Heavy duty Facing Tool

FIG. 96. REPRESENTATIVE TYPES OF CUTTING TOOLS

The clearance and top rake angles specified in Table IX are representative of those adopted for ordinary turning work. The question of top rake plays an important part in the machining of the harder materials or when taking heavy cuts or working with coarse feeds. Under these conditions the top rake should be reduced below the usual figures.

It is essential that a clear distinction should be made between turning and surfacing tools and the top rake with which they are each provided. Fig. 98 illustrates a cutting tool performing surfacing work with a normal amount of top rake provided for operating on steel, and it will be observed that the pressure of the cut on the top of the tool acting in the direction indicated by the arrow tends to deflect the tool

TABLE IX

Clearance and Top Rake Angles of Cutting Tools

FERROUS METALS

Material	Composition C.	Si.	Mn.	S.	P.	Cr.	Ni.	Mo.	Cu.	V.	Condition	Tensile Tons per sq. in.	Elongation %	Brinell Hardness	Front Clearance Angle deg.	Wedge or Cutting Angle deg.	Top Rake Angle deg.
Stainless Iron	·15 max.	·50 max.	—	—	—	12·0 min.	1·0 max.	—	—	—	Bars, Forgings, and Stampings	35–45	25·0 min.	152–207	3–5	76–78	8–10
Stainless Steel	·25 max.	·50 max.	1·0 max.	—	—	16 20	1·0 min.	—	—	—	Do. (Oil Quenched 950–1000° C. Tempered 725–760° C.)	50–60	25–15	240–280			
Alloy Steels	·7	—	·7	—	—	·7	—	—	—	—	Heat-treated	65·0	6·5	280	6–8	78–80	2–4
Do.	·23	·20	·5	—	—	1·58	—	·2	—	1·24	Do.	76·0	12·0	400			
Do.	·3	—	—	—	—	1·5	4·5	—	—	—	Do.	110·0	—	460	6–8	80–82	0–2
Manganese Steel	—	—	12·0	—	—	—	—	—	—	—	—	—	—	200–240	6–8	80–82	0–4
Mild or Medium Tensile Steels	·15	—	·6	·05	·05	—	—	—	—	—	Heat-treated	25–30	23–30	116	10–12	68–72	8–10
Do.	·33	—	·7	·05	·05	—	—	—	—	—	Do.	32–38	26–20	149			
Do.	·43	—	·7	·05	·05	—	—	—	—	—	Do.	40–45	20–15	179	8–10	72–74	6–8
Do.	·5	—	—	·05	·05	—	—	—	—	—	Do.	50–55	13–11	217			
Do.	·6	—	—	·04	·04	—	—	—	—	—	Do.	56–62	13–11	245	8–10	74–76	4–6
Wrought Iron	—	—	·10	—	·22	—	—	—	—	—	—	21–24	25·0	90	8	62	20
Cast Steel	·85	—	—	—	—	—	—	—	—	—	Heat-treated	89·0	5·0	555	8–10	72–74	6–8
Do.	·3	·3 max.	·7	·06	·06	—	—	—	—	—	—	35·0	15·0	156	8	68	14
Do.	·18	·32	·63	·054	·047	—	—	—	—	—	—	27·8	34·0	121	8	62	20
Cast Irons	3·3	1·8	·7	—	—	—	1·5	—	—	—	For Light Sections	18	—	220	8–10	76–80	2–4
Do.	3·2	1·2	·7	—	—	—	1·25	—	—	—	For Medium Sections	18	—	210			
Do.	3·2	1·6	·7	—	—	·5	1·25	—	—	—	Do.	18	—	220			
Do.	3·2	1·0	·7	—	—	·5	1·25	—	—	—	For Heavy Sections	18	—	200			
Do.	3·2	1·2	·8	—	—	1·0	1·0	—	—	—	For Heat Resistance	17	—	250			
Do.	3·9	1·5	·8	—	—	—	1·5	—	—	—	For Max. Strength	22	—	220			
Do.	3·3	1·2	·8	—	—	·5	3·0	—	—	—	Hard Grey	20	—	300	6	84	0
Do.	3·3	1·2	·8	—	—	·75	5·0	—	—	—	Martensitic	20	—	400			
Do.	3·0	1·5	7·0	—	—	—	11·0	—	—	—	"Nomag"	16	—	180	8–10	74–76	4–6
Do.	3·0	1·5	1·0	—	—	2·0	17·5	—	—	—	"NiResist"	16	—	180			
Do.	3·0	1·5	1·0	—	—	2·0	15–22	—	5–7	—	Do. Normal	9–15	—	125–200			
Do.	1·8	4·5	·8	—	—	2·0	18·0	—	—	—	"Nicrostal"	16	—	180			
Do.	2·2	1·5	·8	—	—	2·0	34·0	—	—	—	Low Expansion	14	—	180			

TABLE IX—(*contd.*)

Clearance and Top Rake Angles of Cutting Tools

NON-FERROUS METALS

Material	Composition								Condition	Tensile Tons per sq. in.	Elongation %	Brinell Hardness	Front Clearance Angle deg.	Wedge or Cutting Angle deg.	Top Rake Angle deg.
	Cu.	Zn.	Sn.	P.	Pb.	Ni.	Al.	St.							
Very Brittle Brass	50	50	—	—	—	—	—	—	As Cast	8·8	1	108			
Do.	50	50	—	—	—	—	—	—	Rolled	15·8	5	117	6	84	0
Very Brittle Bronze	85	—	15	·1	—	—	—	—	As Cast	14·0	2	100			
Brass (Ductile)	70	30	—	—	—	—	—	—	As Cast	17·0	58	55			
Do.	70	30	—	—	—	—	—	—	Rolled	35·0	10	150			
Do.	70	30	—	—	—	—	—	—	Annealed	21·5	68	57			
Do.	60	40	—	—	—	—	—	—	As Cast	24·0	50	85			
Do.	60	40	—	—	—	—	—	—	Rolled	26·0	47	90	8	74	8
Do.	60	40	—	—	—	—	—	—	Annealed	24·0	49	79			
Do.	53	47	—	—	—	—	—	—	As Cast	29·9	24	108			
Do.	53	47	—	—	—	—	—	—	Rolled	32·8	28	114			
Do.	53	47	—	—	—	—	—	—	Annealed	29·1	22·5	108			
Bronze (Ductile)	90	—	10	—	—	—	—	—	As Cast	18·0	15·0	60·7	8	55	27
Soft Metals—															
Copper	100	—	—	—	—	—	—	—	As Cast	8·0	11·0	50·0			
									Rolled	17·0	20·0	70·0			
									Annealed	14·0	37·0	40·0			
Lead	—	—	—	—	100	—	—	—		1·0	35·0	7·0			
Nickel	—	—	—	—	—	100	—	—	Rolled	34·0 to 45·0	44·0	85·0			
									Annealed	20·0 to 30·0	12·0	75·0			
									Hard Drawn	50·0	2·0	140			
Zinc	—	100	—	—	—	—	—	—	As Cast	1·0–2·5	Nil	35·0	10	40	40
									Rolled	8·0	—	45·0			
Tin	—	—	100	—	—	—	—	—	As Cast	2·0	79·0	15·0			
Aluminium	—	—	—	—	—	—	100	—	As Cast	3–6	3·0	25·0			
									Rolled	7–12	35·0	40·0			
White Metals	5·0	—	85·0	—	—	—	—	10·0	As Cast	—	—	33·0			
Do.	2·0	—	60·0	—	28·0	—	—	10·0	As Cast	—	—	20·0			
Do.	—	—	12·0	—	75·0	—	—	13·0	As Cast	—	—	19·0			

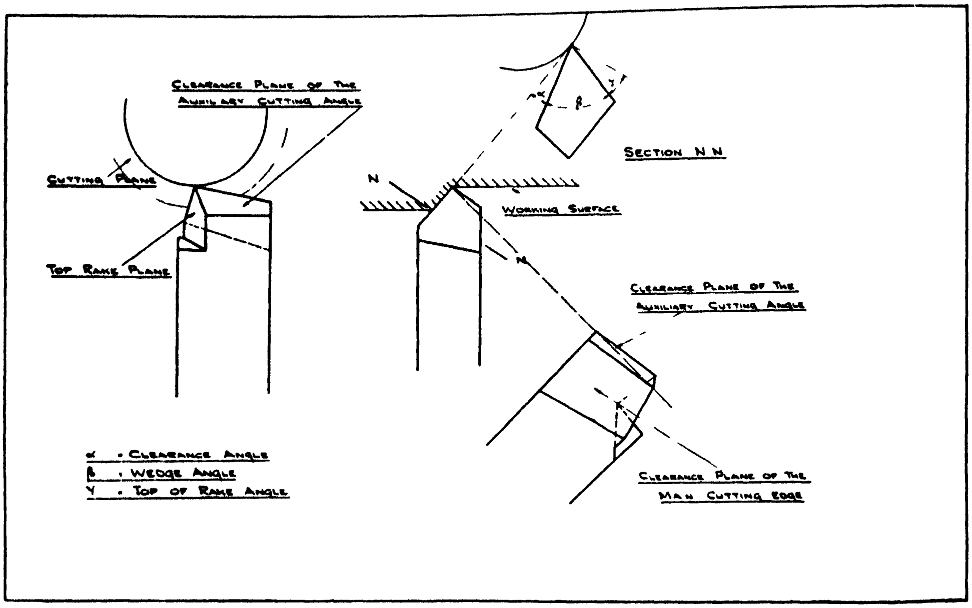


FIG. 97. TOP RAKE, CLEARANCE, AND WEDGE ANGLES OF CUTTING TOOLS

into the solid wall of metal, which in turn tends to increase the depth of cut. The result of this is that the sharp cutting edge of the tool is

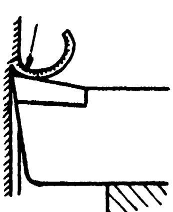


FIG. 98

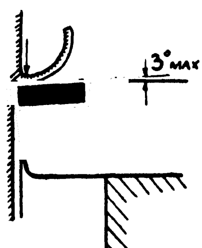


FIG. 99

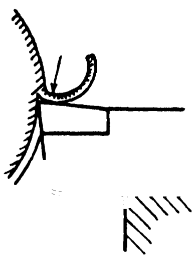


FIG. 100

liable to break, and it has been found that when surfacing operations are to be performed it is better to reduce substantially the top rake to a negative amount, a negative back rake up to 3° having been found to be a decided advantage. In these circumstances, as will be seen from Fig. 99, the pressure of the chip on the top of the tool is acting vertically downward with a corresponding tendency to cause the tool to back away from the work. Swarf may be cleared by a few degrees side rake.

In the case of turning tools, any deflection produced in the tool by the pressure of the cut is provided for by the fact that on the radius of the work being carried out space is allowed for the tool to back away as shown in Fig. 100, and, furthermore, the forward movement of the tool itself also neutralizes any tendency to deflection. To ensure that adequate provision is made for this condition, however, it is suggested that whenever possible the

front cutting edge of the tool should be $\frac{1}{32}$ in. below the centre line for work up to 4 in. diameter, and $\frac{1}{16}$ in. below the centre for work above 4 in. diameter.

Setting of Tool in Machine

Vibration, deflection, and lack of rigidity are the greatest foes of cutting tools, and machine operators and all others concerned should fully appreciate this fact.

Any tool will deflect under load, and the larger the overhang of the tool, the greater will be the deflection. If a tool with only $\frac{1}{2}$ in. overhang deflects 0·0001 in., then by the law governing the deflection of beams the same tool with a 2 in. overhang will deflect 0·0064 in., and this is excessive for any carbide tool. Minimum overhang, as illustrated in Fig. 101, means minimum trouble.

Finally a word of caution—negligent handling may easily damage a valuable tool and great care should be exercised in using, storing, and packing carbide tools and tips.

Twist Drills

Although it is best to have a special shape of twist drill for every kind of material, this is seldom practicable as the costs are too high. There should, however, be at least three different types of twist drills—

(1) Drills for cast iron and steel.

(2) Drills for copper alloys (brass).

(3) Drills for soft light metals.

Commercial Measurement Considerations

It is necessary to understand the meaning of certain terms used in the manufacture of engineering products. These are as follows—

(1) *Limits.* The extreme dimensions prescribed for variations in both fit and workmanship.

(2) *Allowance.* A difference in dimensions prescribed in order to allow of various qualities of fit.

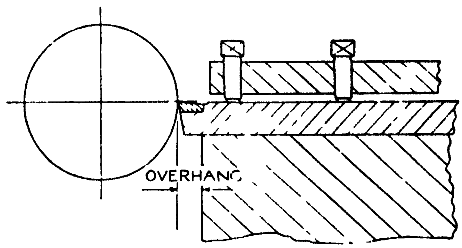


FIG. 101. CORRECT SETTING UP OF TOOL IN MACHINE

(3) *Maximum Allowance.* The difference between the smallest shaft and the largest hole.

(4) *Minimum Allowance.* The difference between the largest shaft and the smallest hole.

(5) *Tolerance.* A difference in dimensions prescribed in order to tolerate unavoidable imperfections in workmanship.

(6) *Gross Tolerance* is the maximum tolerance permissible for a given quality of fit.

(7) *Net Tolerance.* The tolerance available for the actual manufacturing operation after deducting from the gross tolerance (*a*) all measurement errors, (*b*) tolerance for gauge making, and (*c*) amount allowed for gauge wear.

Fig. 102 serves to illustrate the difference between the terms "tolerance" and "allowance." All too frequently these terms are confused,

although they have entirely different meanings.

It will be realized that the coarser the tolerance actually available, the cheaper can an article be manufactured. The question arises, therefore, as to how tolerance can be increased without impairing the functioning qualities of the mechanism. Investigation should always be made to see

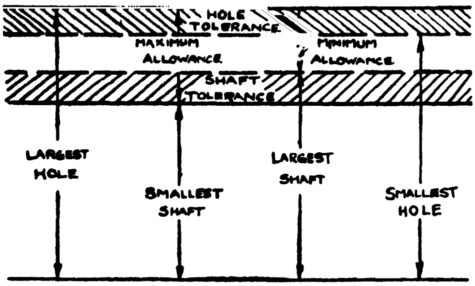


FIG. 102. DIFFERENTIATION BETWEEN THE TERMS "TOLERANCE" AND "ALLOWANCE"

whether working tolerances can be increased by more accurate means of measurement.

With any mechanism the correct functioning of the component parts depends on the differences in size and finish of the contracting surfaces. For example, if a gear has to slide along a shaft and the shaft is made larger than the hole, then it will not enter. If, on the other hand, the shaft is much smaller than the hole, the gear will be too loose. There is, however, a small margin where a satisfactory sliding fit can be obtained, and it is within this margin that variations of size can be permitted.

In every instance there are high and low limits which bound this margin, the high limit being the maximum allowance or the greatest difference allowable between the two parts, whilst the low limit is the minimum allowance or the smallest difference allowable for the desired fit. Between these two limits both shaft and hole can vary in size, and the amount of permissible variation is the combined gross tolerances of the two parts as can be deduced from Fig. 102. The gross tolerance must include not only the actual manufacturing tolerance but also the tolerances required (1) for making the gauges, (2) to permit a certain amount of gauge wear, and (3) to cover unavoidable errors of measurement.

It is often quite wrongly assumed that the tolerances specified on drawings are the tolerances actually available for manufacturing purposes. In the first place, the gauges themselves cannot be made without a tolerance of their own; secondly, allowance must be made for gauge wear, otherwise the gauges will be useless as soon as wear commences; and, thirdly, the lack of exactness in measurement must be taken into account. If these three items were added to the tolerance on the drawing, then there would be no safeguard to prevent the functioning allowance from being made too large and probably the parts would not fit together. Accordingly, the drawing tolerance must always be regarded as the gross tolerance.

Repetition work would be impracticable if there were no means of making details interchangeable. This is achieved by some approved system of allowances and tolerances combined with a properly designed scheme of

gauging, usually by means of limit gauges.

Maximum and Minimum Allowances

When considering the amounts of allowances and tolerances to suit each class of fit, the correct procedure is to determine by trial or experiment the maximum and minimum allowances that will give the required functioning quality. The difference between these is the combined tolerances available for both mating components and the total amount can be divided between the two parts in accordance with any prearranged system, one of the best known being that of the Newall system.

Uniformity in the size of holes is the beginning of any system of accurate or interchangeable work, and, as holes are usually finished by reamers and other set tools and can by such means be duplicated in size with reasonable commercial accuracy, the Newall system is founded upon "hole basis," i.e. provision is made in the size of the hole for error in workmanship only. To obtain the quality of fit desired suitable variation is allowed on the size of the shaft or pin which has to go into the hole. Admittedly it is easier in practice to vary the size of the shaft than that of the hole: if the system of "hole basis" is not chosen and preference is given to the opposite system, "shaft basis," then the size of the hole must be varied, and this will necessitate the provision of an additional reamer or suitable tool for each quality of fit that may be required for every diameter used. The cost of such an outfit of wearable tools and the added difficulty of keeping these up to standard, entailing considerable trouble and expense, is a decided factor in favour of "hole basis." There are, of course, some classes of work—the exceptions that prove the rule—for which, notwithstanding the increased cost entailed, the system of "shaft basis" is the more suitable.

Tolerances for standard holes are in two grades, Classes A and B, the selection of which is for the user's decision and dependent upon the quality of the work required: some prefer to use Class A as working limits and Class B as inspection limits. Allowances for shafts are as follows—

Force Fits, Class F. The shafts made to this table will require either hydraulic pressure to force them into the holes or the expansion of the holes by heating so as to shrink them on to the shafts.

Driving Fits, Class D, will produce shafts that need to be driven into the holes.

Push Fits, Class P. Shafts made to these limits can be pushed into the holes, but will not be sufficiently free to rotate without seizing.

Running Fits—the most commonly required—are divided into three grades—

Class X for engine and other work where easy fits are wanted.

Class Y for high speeds and good average machine work.

Class Z for fine tool work.

Note. The Running Fit classes may be employed for other than revolving fits where it may be advisable or necessary to limit the productive error.

Tables X and XI give tolerances and allowances for all these classes in

TABLE X

Tolerances and Allowances (English Dimensions)

(For Sizes up to 6 in.)

TOLERANCES IN STANDARD HOLES

Class	Nominal Diameters	Up to and including ½ in.	Above ½ in. up to 1 in.	Above 1 in. up to 2 in.	Above 2 in. up to 3 in.	Above 3 in. up to 4 in.	Above 4 in. up to 5 in.	Above 5 in. up to 6 in.
A	High Limit Low Limit Tolerance	+ ·00025 − ·00025 ·00050	+ ·00050 ·00025 ·00075	+ ·00075 − ·00025 ·00100	+ ·00100 − ·00050 ·00150	+ ·00100 ·00050 ·00150	+ ·00100 − ·00050 ·00150	+ ·00150 − ·00050 ·00200
B	High Limit Low Limit Tolerance	+ ·00050 − ·00050 ·00100	+ ·00075 ·00050 ·00125	+ ·00100 − ·00050 ·00150	+ ·00125 ·00075 ·00200	+ ·00150 ·00075 ·00225	+ ·00175 − ·00075 ·00250	+ ·00200 − ·00100 ·00300

ALLOWANCES ON SHAFTS FOR VARIOUS FITS

Force Fits

Class	Nominal Diameters	Up to and including ½ in.	Above ½ in. up to 1 in.	Above 1 in. up to 2 in.	Above 2 in. up to 3 in.	Above 3 in. up to 4 in.	Above 4 in. up to 5 in.	Above 5 in. up to 6 in.
F	High Limit Low Limit Tolerance	+ ·00100 + ·00050 ·00050	+ ·00200 + ·00150 ·00050	+ ·00400 + ·00300 ·00100	+ ·00600 + ·00450 ·00150	+ ·00800 + ·00600 ·00200	+ ·01000 + ·00800 ·00200	+ ·01200 + ·01000 ·00200

Driving Fits

Class	Nominal Diameters	Up to and including ½ in.	Above ½ in. up to 1 in.	Above 1 in. up to 2 in.	Above 2 in. up to 3 in.	Above 3 in. up to 4 in.	Above 4 in. up to 5 in.	Above 5 in. up to 6 in.
D	High Limit Low Limit Tolerance	+ ·00050 + ·00025 ·00025	+ ·00100 + ·00075 ·00025	+ ·00150 + ·00100 ·00050	+ ·00250 + ·00150 ·00100	+ ·00300 + ·00200 ·00100	+ ·00350 + ·00250 ·00100	+ ·00400 + ·00300 ·00100

Push Fits

Class	Nominal Diameters	Up to and including ½ in.	Above ½ in. up to 1 in.	Above 1 in. up to 2 in.	Above 2 in. up to 3 in.	Above 3 in. up to 4 in.	Above 4 in. up to 5 in.	Above 5 in. up to 6 in.
P	High Limit Low Limit Tolerance	− ·00025 − ·00075 ·0005	− ·00025 − ·00075 ·0005	− ·00025 − ·00075 ·0005	− ·0005 − ·0010 ·0005	− ·0005 − ·0010 ·0005	− ·0005 − ·0010 ·0005	− ·0005 − ·0010 ·0005

Running Fits (3 *grades*)

Class	Nominal Diameters	Up to and including ½ in.	Above ½ in. up to 1 in.	Above 1 in. up to 2 in.	Above 2 in. up to 3 in.	Above 3 in. up to 4 in.	Above 4 in. up to 5 in.	Above 5 in. up to 6 in.
X	High Limit Low Limit Tolerance	− ·00100 − ·00200 ·00100	− ·00125 − ·00275 ·00150	− ·00175 − ·00350 ·00175	− ·00200 − ·00425 ·00225	− ·00250 − ·00500 ·00250	− ·00300 − ·00575 ·00275	− ·00350 − ·00650 ·00300
Y	High Limit Low Limit Tolerance	− ·00075 − ·00125 ·00050	− ·00100 − ·00200 ·00100	− ·00125 − ·00250 ·00125	− ·00150 − ·00300 ·00150	− ·00200 − ·00350 ·00150	− ·00225 − ·00400 ·00175	− ·00250 − ·00450 ·00200
Z	High Limit Low Limit Tolerance	− ·00050 − ·00075 ·00025	− ·00075 − ·00125 ·00050	− ·00075 − ·00150 ·00075	− ·00100 − ·00200 ·00100	− ·00100 − ·00225 ·00125	− ·00125 − ·00250 ·00125	− ·00125 − ·00275 ·00150

TABLE X—(*contd.*)

Tolerances and Allowances (English Dimensions)

(For Sizes over 6 in. up to 12 in.)

TOLERANCES IN STANDARD HOLES

Class	Nominal Diameters	Above 6 in. up to 7 in.	Above 7 in. up to 8 in.	Above 8 in. up to 9 in.	Above 9 in. up to 10 in.	Above 10 in. up to 11 in.	Above 11 in. up to 12 in.
A	High Limit Low Limit Tolerance	+ ·00150 − ·00075 ·00225	+ ·00175 − ·00075 ·00250	+ ·00175 − ·00100 00275	+ ·00175 − ·00100 ·00275	+ ·00200 − ·00100 ·00300	+ ·00200 − ·00100 ·00300
B	High Limit Low Limit Tolerance	+ ·00225 − ·00100 ·00325	+ ·00225 − ·00125 ·00350	+ ·00250 − ·00125 ·00375	+ 00250 − 00125 ·00375	+ ·00275 − ·00125 ·00400	+ ·00275 − ·00150 ·00425

ALLOWANCES ON SHAFTS FOR VARIOUS FITS

Force Fits

Class	Nominal Diameters	Above 6 in up to 7 in.	Above 7 in. up to 8 in.	Above 8 in. up to 9 in.	Above 9 in. up to 10 in.	Above 10 in. up to 11 in.	Above 11 in. up to 12 in.
F	High Limit Low Limit Tolerance	+ ·014 + ·012 ·002	+ ·016 + ·014 ·002	+ ·018 + ·016 002	+ ·020 + ·018 ·002	+ ·022 + ·020 ·002	+ ·024 + ·022 ·002

Driving Fits

Class	Nominal Diameters	Above 6 in. up to 7 in	Above 7 in. up to 8 in.	Above 8 in up to 9 in.	Above 9 in. up to 10 in.	Above 10 in up to 11 in.	Above 11 in. up to 12 in.
D	High Limit Low Limit Tolerance	+ ·00450 + 00300 ·00150	+ ·00500 + ·00350 00150	+ ·00550 + 00400 ·00150	+ 00600 + 00450 ·00150	+ ·00650 + ·00450 ·00200	+ 00700 + 00500 ·00200

Push Fits

Class	Nominal Diameters	Above 6 in. up to 7 in.	Above 7 in. up to 8 in.	Above 8 in. up to 9 in.	Above 9 in up to 10 in	Above 10 in. up to 11 in.	Above 11 in. up to 12 in.
P	High Limit Low Limit Tolerance	− ·00050 ·00125 ·00075	00050 − 00150 ·00100	00050 00150 00100	00075 00200 00125	− 00075 − 00200 00125	− ·00075 − ·00200 ·00125

Running Fits (3 *grades*)

Class	Nominal Diameters	Above 6 in. up to 7 in.	Above 7 in. up to 8 in.	Above 8 in. up to 9 in.	Above 9 in. up to 10 in.	Above 10 in. up to 11 in.	Above 11 in. up to 12 in.
X	High Limit Low Limit Tolerance	− ·00350 − ·00675 ·00325	− ·00350 − ·00700 ·00350	− ·00375 − 00750 ·00375	− ·00400 − ·00800 ·00400	− 00400 − ·00825 ·00425	− ·00425 − ·00850 ·00425
Y	High Limit Low Limit Tolerance	− ·00275 − ·00475 ·00200	− ·00275 − ·00500 ·00225	− ·00300 − ·00550 ·00250	− ·00325 − 00575 ·00250	− ·00325 − ·00600 ·00275	− ·00350 − ·00625 ·00275
Z	High Limit Low Limit Tolerance	− ·00125 − ·00275 ·00150	− ·00150 − ·00300 ·00150	− ·00150 − ·00300 ·00150	− ·00150 − 00325 ·00175	− ·00175 − ·00350 ·00175	− ·00175 − ·00350 ·00175

TABLE XI

Tolerances and Allowances (Metric Dimensions)

(For Sizes up to 150 millimetres)

TOLERANCES IN STANDARD HOLES

Class	Nominal Diameters	Up to and including 15	Over 15 up to 25	Over 25 up to 50	Over 50 up to 75	Over 75 up to 100	Over 100 up to 125	Over 125 up to 150
A	High Limit	+ ·007	+ ·013	+ ·019	+ ·026	+ ·026	+ ·026	+ ·039
	Low Limit	− ·007	− ·007	− ·007	− ·013	− ·013	− ·013	− ·013
	Tolerance	·014	·020	·026	·039	·039	·039	·052
B	High Limit	+ ·013	+ ·019	+ ·026	+ ·032	+ ·039	+ ·045	+ ·051
	Low Limit	− ·013	− ·013	− ·013	− ·019	− ·019	− ·019	− ·026
	Tolerance	·026	·032	·039	·051	·058	·064	·077

ALLOWANCES ON SHAFTS FOR VARIOUS FITS

Force Fits

Class	Nominal Diameters	Up to and including 15	Over 15 up to 25	Over 25 up to 50	Over 50 up to 75	Over 75 up to 100	Over 100 up to 125	Over 125 up to 150
F	High Limit	+ ·026	+ ·051	+ ·102	+ ·153	+ ·204	+ ·255	+ ·306
	Low Limit	+ ·013	+ ·038	+ ·077	+ ·115	+ ·152	+ ·203	+ ·254
	Tolerance	·013	·013	·025	·038	·052	·052	·052

Driving Fits

Class	Nominal Diameters	Up to and including 15	Over 15 up to 25	Over 25 up to 50	Over 50 up to 75	Over 75 up to 100	Over 100 up to 125	Over 125 up to 150
D	High Limit	+ ·013	+ ·026	+ ·039	+ ·064	+ ·077	+ ·089	+ ·102
	Low Limit	+ ·007	+ ·019	+ ·026	+ ·039	+ ·051	+ ·063	+ ·076
	Tolerance	·006	·007	·013	·025	·026	·026	·026

Push Fits

Class	Nominal Diameters	Up to and including 15	Over 15 up to 25	Over 25 up to 50	Over 50 up to 75	Over 75 up to 100	Over 100 up to 125	Over 125 up to 150
P	High Limit	− ·006	− ·006	− ·006	− ·012	− ·012	− ·012	− ·012
	Low Limit	− ·019	− ·019	− ·019	− ·026	− ·026	− ·026	− ·026
	Tolerance	·013	·013	·013	·014	·014	·014	·014

Running Fits (*3 grades*)

Class	Nominal Diameters	Up to and including 15	Over 15 up to 25	Over 25 up to 50	Over 50 up to 75	Over 75 up to 100	Over 100 up to 125	Over 125 up to 150
X	High Limit	− ·025	− ·032	− ·045	− ·051	− ·063	− ·076	− ·089
	Low Limit	− ·051	− ·070	− ·090	− ·108	− ·127	− ·146	− ·165
	Tolerance	·026	·038	·045	·057	·064	·070	·076
Y	High Limit	− ·019	− ·025	− ·032	− ·038	− ·051	− ·057	− ·063
	Low Limit	− ·032	− ·051	− ·064	− ·076	− ·089	− ·101	− ·114
	Tolerance	·013	·026	·032	·038	·038	·044	·051
Z	High Limit	− ·012	− ·019	− ·019	− ·025	− ·025	− ·032	− ·032
	Low Limit	− ·019	− ·032	− ·039	− ·051	− ·057	− ·064	− ·070
	Tolerance	·007	·013	·020	·026	·032	·032	·038

TABLE XI—(*contd.*)

Tolerances and Allowances (Metric Dimensions)

(For Sizes over 150 up to 300 millimetres)

TOLERANCES IN STANDARD HOLES

Class	Nominal Diameters	Over 150 up to 175	Over 175 up to 200	Over 200 up to 225	Over 225 up to 250	Over 250 up to 275	Over 275 up to 300
A	High Limit Low Limit Tolerance	+ 039 − 019 058	+ 044 − 022 066	+ 044 − 025 069	+ 044 025 069	+ 051 − 025 076	+ 051 − 025 076
B	High Limit Low Limit Tolerance	+ 057 − 026 083	+ 057 − 032 089	+ 063 032 095	+ 063 032 095	+ 070 032 102	+ 070 − 038 108

ALLOWANCES ON SHAFTS FOR VARIOUS FITS

Force Fits

Class	Nominal Diameters	Over 150 up to 175	Over 175 up to 200	Over 200 up to 225	Over 225 up to 250	Over 250 up to 275	Over 275 up to 300
F	High Limit Low Limit Tolerance	+ 358 + 306 052	+ 410 + 358 052	+ 462 + 410 052	+ 514 + 462 052	+ 566 + 514 052	+ 618 + 566 052

Driving Fits

Class	Nominal Diameters	Over 150 up to 175	Over 175 up to 200	Over 200 up to 225	Over 225 up to 250	Over 250 up to 275	Over 275 up to 300
D	High Limit Low Limit Tolerance	+ 114 + 076 038	+ 127 + 089 038	+ 140 + 102 038	+ 152 + 114 038	+ 165 + 114 051	+ 178 + 127 051

Push Fits

Class	Nominal Diameters	Over 150 up to 175	Over 175 up to 200	Over 200 up to 225	Over 225 up to 250	Over 250 up to 275	Over 275 up to 300
P	High Limit Low Limit Tolerance	− 013 032 019	− 013 − 038 025	013 − 038 025	019 − 051 032	019 051 032	− 019 − 051 032

Running Fits (3 *grades*)

Class	Nominal Diameters	Over 150 up to 175	Over 175 up to 200	Over 200 up to 225	Over 225 up to 250	Over 250 up to 275	Over 275 up to 300
X	High Limit Low Limit Tolerance	− 089 − 171 082	− 089 − 179 090	095 − 191 096	− 102 − 203 101	102 − 210 108	− 108 − 216 108
Y	High Limit Low Limit Tolerance	− 070 − 121 051	− 070 − 127 057	076 140 064	− 083 147 064	083 152 069	− 089 − 158 069
Z	High Limit Low Limit Tolerance	− 032 − 070 038	− 038 − 076 038	− 038 − 076 038	− 038 − 083 045	− 044 − 089 045	− ·044 − ·089 ·045

both English and metric dimensions, for sizes up to and including 12 in. and 800 mm. respectively. As factors other than nominal size have a very important bearing on the eventual results obtained in the case of force and driving fits, e.g. materials, shape of pieces, length of bearing, and finish

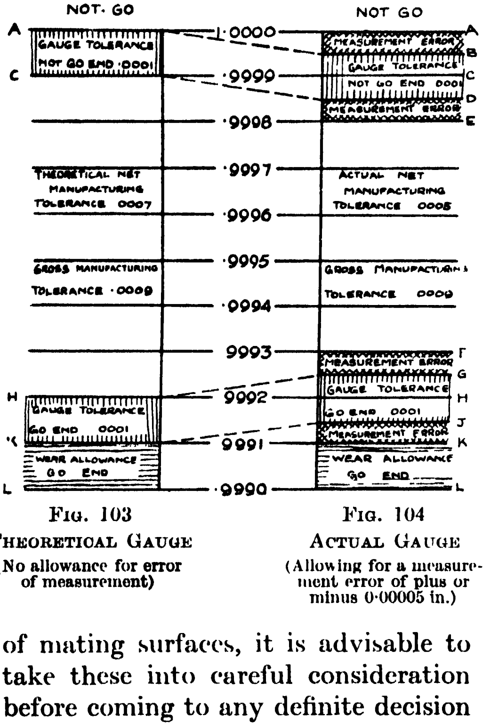


FIG. 103
THEORETICAL GAUGE
(No allowance for error of measurement)

FIG. 104
ACTUAL GAUGE
(Allowing for a measurement error of plus or minus 0·00005 in.)

of mating surfaces, it is advisable to take these into careful consideration before coming to any definite decision in regard to these two classes of fit.

It should be noted that when the hole tolerance is subtracted from the combined tolerance the amount available for the shaft tolerance is obtained. To take a hypothetical example, let it be assumed that a running fit is required on a nominal 1 in. diameter shaft and hole.

(*a*) Maximum allowance, say .	0025 in.
(*b*) Minimum allowance, say .	·0010 in.
(*c*) Difference ($a - b$) = combined hole and shaft tolerance . . .	0015 in.

(*d*) Hole tolerance . .	·0007 in.	
(*e*) Shaft tolerance ($c - d$)	·0008 in.	
(*f*) Largest hole, say . .	1·0005 in.	·0025 in. maximum allowance
(*g*) Smallest shaft ($f - g = a$)	·9980 in.	
(*h*) Smallest hole ($f - h = d$) .	·9998 in.	·0010 in. minimum allowance
(*j*) Largest shaft ($h - j = b$) .	·9988 in.	

It is hardly necessary to say that in fixing the maximum and minimum allowances (*a*) and (*b*), and the size of the largest hole (*f*), skilled judgment based on considerable experience and experiment is required. It is, of course, desirable that the combined hole and shaft tolerance (*c*) should be as large as possible, on the strict understanding that it must not be exceeded either through errors or vagueness of measurement, or by gauge wear.

Principles of Gauge Manufacture

Once the various allowances and tolerances have been decided upon for any pair of mating parts the next step is the making of the gauges in the tool room. Consider a double-ended plug gauge for measuring a hole. Starting with the theoretically correct sizes, maximum diameter 1·0000 in. and minimum diameter 0·9990 in., two parallel lines *A* and *L* can be drawn, the distance between them representing the difference or tolerance 0·0010 in. If measurements could be guaranteed exact, the gauge could be made, as shown graphically in Fig. 103, with a maximum and minimum difference between the "Go" and "Not go" ends of 0·0009 in. and 0·0007 in. respectively; in other words, the boundaries of the two ends of the gauge would lie between *AC* on the large end and *HK* on the small end. Then the "Go" end could be allowed to

wear until it measured 0·9990 in. after which it would be scrapped.

In Fig. 104 is seen the result obtained when the measuring instruments can safely be read within the reasonable latitude of plus or minus 50 millionths or 0·00005 in. As it is not allowable to transgress beyond the lines *A* and *K* in making the gauge, the actual tolerance boundaries have to be moved from *AC* and *HK* in Fig. 103 to *BD* and *GJ* in Fig. 104. At the same time the inaccuracy of measurement will possibly move the lines *D* and *G* to positions *E* and *F*, thus reducing the theoretical net tolerance of 0·0007 in. to an actual net tolerance of 0·0005 in., the gross tolerance being the same both theoretically and actually. Thus the measurement error has reduced the net tolerance by four times its own amount.

This vagueness or inaccuracy of measurement is not vital where only one gauge is to be made, but when duplicates or replacements are required it is very important, as will be known by those who have tried to get interchangeable parts manufactured in different works. To illustrate this point, four new double-ended plug gauges of the same nominal size and tolerance were carefully measured in a machine guaranteed to measure accurately within 10 millionths (0·00001 in.), the result being shown graphically in Fig. 105.

If an operator uses gauge No. 1 for producing a hole to be inspected later by gauge No. 3, then the only holes passed by the inspector will be produced within a net tolerance of 0·00034 in., whereas if gauges Nos. 4 and 2 are used by operator and inspector respectively, the net tolerance for the holes passed will be 0·00043 in. These four gauges are supposed to be the same, and the differences between them are due to errors of measurement. If the accuracy of measurement could be relied upon within 0·00005 in., then the same four gauges with the

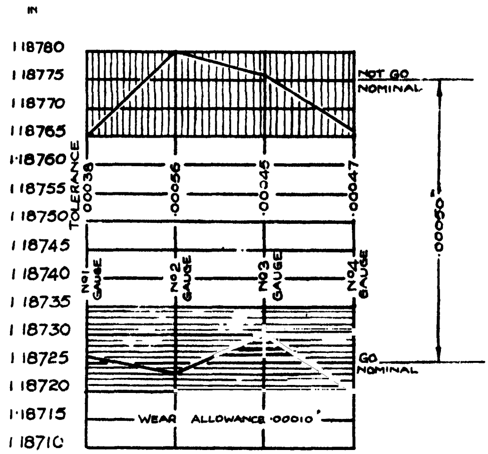


FIG. 105. GRAPHICAL COMPARISON OF FOUR DOUBLE-ENDED PLUG GAUGES
(Measured to plus and minus 0·00001 in.)

same gross tolerance of 0·0007 in. would have a net tolerance, allowing 0·0001 in. for wear, of 0·0005 in., and it would be much cheaper to produce holes to an actual manufacturing tolerance of 0·0005 in. than is the case with the gauges as they are shown in Fig. 105. This proves conclusively that exactness of measurement is highly important in decreasing production costs, and every step should be taken to ensure it.

Internal and External Limit Gauges

The general method of construction employed in the manufacture of internal limit gauges is that of building

up the two gauge plugs on a handle with provision for renewal or exchange of plugs when worn, or as may be necessary. In the larger sizes where sensitivity in handling may be adversely affected by excessive weight, the plugs should be of shell form secured to an aluminium handle portion.

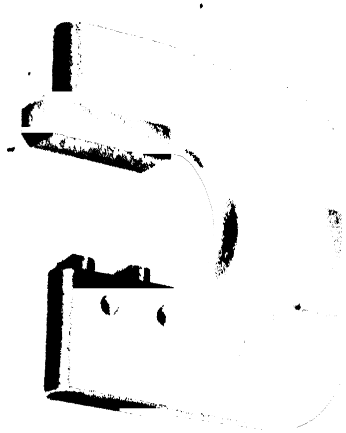


FIG. 106. ADJUSTABLE EXTERNAL LIMIT GAUGE

The provision of a separate external limit gauge for each diameter used, and for each variation in the quality of fit required on such diameter, would entail in many cases an expenditure so heavy as to prohibit the installation of a full equipment: yet in modern commercial production efficient means of gauging work are imperative, and, to overcome the necessity for the multiplicity of external limit gauges required, an adjustable type is frequently used. This reduces to a minimum the initial outlay upon the outfit of limit gauges for external work, it can be advantageously employed on either the finest or roughest class of production, and being adjustable it is not affected by wear as are solid gauges.

Fig. 106 is an example of an adjustable external limit gauge. The body, or frame, which is of decarbonized cast iron, is of a section specially designed to ensure maintenance of truth and rigidity. One jaw carries an elongated solid anvil of rectangular shape (so secured in the frame as to be practically integral with it) hardened, ground, and lapped to a true plane surface of an area amply sufficient to cover the field of contact with the two circular-faced movable anvils sliding in the opposite jaw. These movable anvils, also hardened and ground, are non-rotating; their gauge faces are lapped truly parallel with that of the fixed anvil and their total capacity of adjustment inwards or outwards is $\frac{1}{4}$ in. By means of locking screws they may be secured independently and positively to "Go" and "Not Go" sizes at any desired point within the range given. A slight chamfer on the front of all gauging faces makes a lead on approach to the piece being tested; a recess in the frame at the rear of the two movable anvils provides for sealing after adjustment to size and limits and before issue to the factory.

Screw Threads

The form of screw threads varies considerably, the shape of the thread being determined to a great extent by the purpose for which it is intended, but for reasons of interchangeability it is important that there should be

uniformity in the sizes or angles of the same form. Various attempts have been made to standardize threads, but owing to the fact that each country has adopted its own standard, this becomes a matter of considerable difficulty.

The principal conditions to be fulfilled by a screw thread are: (1) efficiency; (2) strength; (3) durability.

(1) The efficiency depends on the pitch and the friction, and hence on the pitch and form of thread.

(2) The strength depends on the form or the shearing thickness and depth, or area of the cross-section parallel to the axis.

(3) The durability depends chiefly on the depth that is, upon the extent of bearing surface.

Errors of Screw Threads

The Whitworth Vee thread has seven elements, error on any one of which may be sufficient to cause a gauge to reject work which ought to pass, or vice versa. These elements are –

Full diameter.
Core diameter.
Effective diameter.
Pitch.
Angle.
Radius at crest.
Radius at root.

Of these, "pitch," "effective diameter," and "angle" are the most important, and are those in which errors most frequently occur.

Pitch. The pitch of a thread is the distance it will move in the direction of its axis in one revolution through a fixed nut. It is convenient to distinguish between the following types of error in pitch—

(1) The error in a screw whose pitch is uniform, but longer or shorter than its nominal value, is called "progressive error."

(2) Errors which vary in magnitude when measured from thread to thread along the screw, and which recur at regular intervals, are called "periodic errors." A screw having errors which vary in magnitude when measured over equal fractions of one turn of the thread is usually called "drunken."

(3) An error in pitch which varies irregularly in magnitude when measured over equal lengths of the thread is usually described as "erratic."

Thread roller gauges are recommended as constituting one of the most satisfactory methods of gauging the Whitworth Vee thread on a production basis.

Transference of Size

Accurate end standards are available at a cost cheap enough to warrant their use for all classes of work. Efficient means should be adopted for transferring their accuracy to the gauges so that the cost incurred is in reasonable proportion to the cost of the finished product. Although the micrometer is one of the most generally useful of measuring instruments, it is by no means a tool of the highest order of accuracy, being reliable only to within 0·001 in. There is, however, a variety of appliances in use ranging from the micrometer to the highly accurate measuring machines employed by such institutions as the National Physical Laboratory.

Accurate Measuring Instruments

Gauging in machine tool manufacture and similar high-class work resolves itself into two major problems: first, the provision and maintenance of a standard of length; second, the transference of that standard of length to the component. It is recommended that the standard of length should comprise one set of reference slip gauges and one set of reference length bars. To ensure accuracy these should be compared with the standard yard, by the submission of reference slip gauges and standard length bars to the National Physical Laboratory every twelve months. Substandards of length should be compared with the reference set every three months, the check being carried out on an instrument capable of measuring differences as small as one-millionth of an inch. Table XII gives practical suggestions to form a basis for a complete range of gauges.

TABLE XII

SUGGESTED BASIS FOR COMPLETE RANGE OF GAUGES

Set No.	Location of Gauges	Purpose for which required	Allowance
			in.
1	Gauge control room	For use in conjunction with gauge control room instruments	– ·00002
2	Tool room gauge inspection department	For checking gauges in course of manufacture	– ·00003
3	Machine shop gauge stores	For observing condition of gauges after use	– ·00005
4	General gauge makers	For setting snap gauges	– ·00008
5	Final inspection of tools and fixtures	For checking gear centres and slots	·00010
6	Jig boring department	For accurate setting of work tables	·00020
7	Fitting and grinding department	For jig setting and micrometer checking	·00030

The accurate measuring devices used in the manufacture of precision gauges should only be handled by fully competent and experienced staff. A standard gauge and tool measuring room should always be provided and, for preference, should be located within the tool room (see Fig. 107). If the room is temperature controlled, maintained say at 68° F., and kept within ± 2° F., the test results will not vary due to changes of temperature. Periodical inspection of all gauges should be made and a record of the inspection entered giving date and condition, any necessary adjustment or replacement being carried out immediately it is deemed advisable.

Universal Pitch Measuring Machine. This machine (Fig. 108) has been designed for the accurate determination of the pitch of internal and external threads on parallel and taper work to N.P.L. limits. The principle of measurement involves the use of a high-precision micrometer and a high-amplification mechanical indicator. The use of ground and lapped vees and hardened steel balls ensures practically frictionless slides which give that delicacy of adjustment so

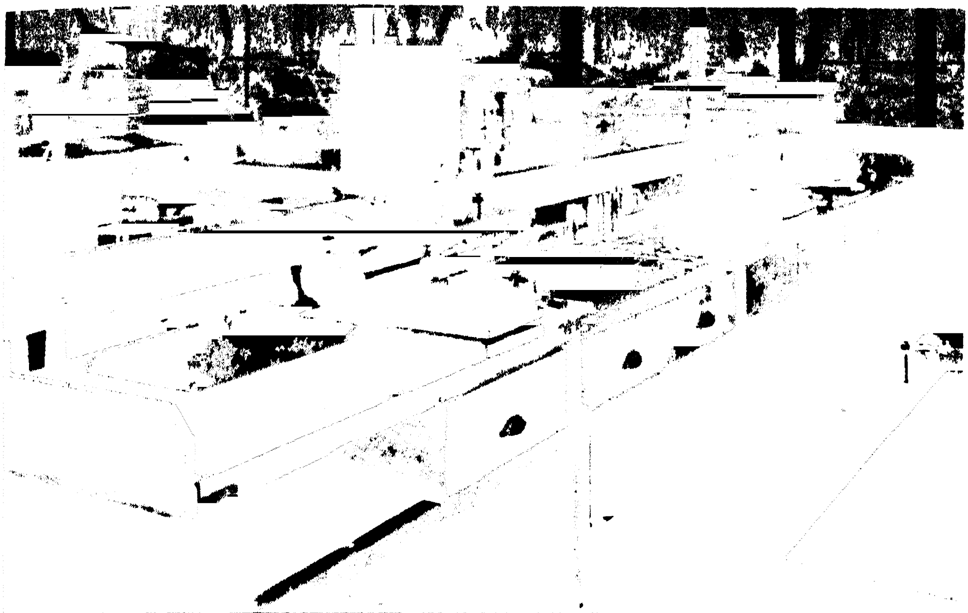


FIG 107 GAUGE AND TOOL MEASURING ROOM

essential in fine measuring instruments. The machine will take up to a maximum diameter of 8 in., and a maximum length of 18 in.

The micrometer as a unit consists of the high-precision screw mounted on bearings at each end, with the anchored central nut completely housed in a two-part casing fixed in the raised arm of the carriage The micrometer screw, which has a hardened and ground thread, is $\frac{5}{8}$ in. diameter with a pitch of 0·025 in. and a total travel of 2·1 in. A graduated disc unit is taper mounted on the end of the screw and is arranged to carry a series of graduated discs. One of these discs is divided into 250 divisions each representing 0·0001 in. with figures at each tenth division. The small divisions representing 0·0001 in. are approximately 0·05 in. apart. The zero index is marked on a ball bearing ring carried on an extension tube

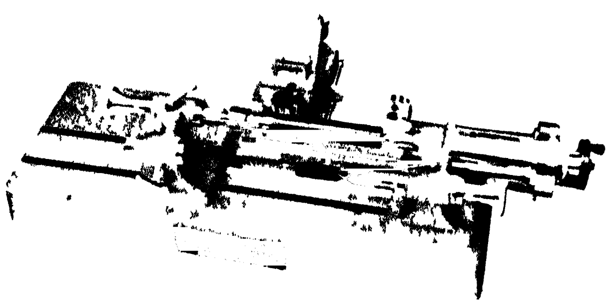


FIG 108 UNIVERSAL PITCH MEASURING MACHINE

attached to the fixed headstock. From this ring projects a pin which engages with an adjustable pitch corrector bar attached to the end of the carriage, contact being maintained by means of a tension spring. An index pin carried from the top of the raised arm of the carriage moves in a slot in the top of

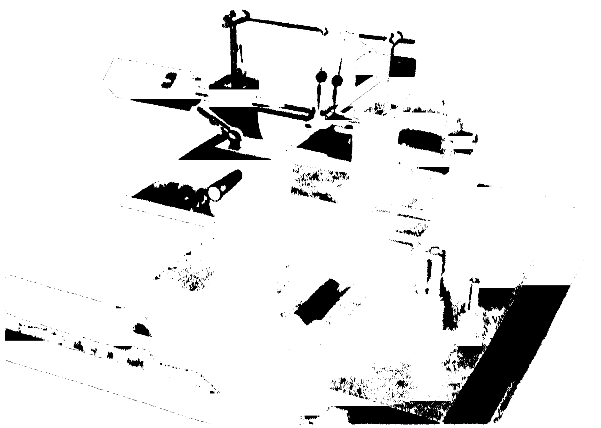


Fig. 109. Floating Carriage Diameter Measuring Machine

the extension tube. The edge of the slot is graduated at intervals of 0·05 in. over a range of minus 0·05 in. to plus 2·05 in. giving approximately 0·05 in. at each end of the normal run of 2 in.

Having arranged that the disc reads zero in the first thread, the micrometer is turned slowly so as to bring the indicator to its mark in each successive thread. At each setting of the indicator the reading of the disc is taken. Having reached the end of the thread, a check reading should be taken on the first thread, and this should check back to within 0·00002 in. or 0·00003 in.

Specially divided discs supplied with the machine will be found to facilitate the measurement of pitch of all screws having any of the ordinary number of threads per inch. Having attached the appropriate discs to the micrometer spindle, the set-up is so arranged that, with the stylus in the first thread of the work, one of the lines on the disc reads exactly opposite the central "5" line on the short scale on the left-hand fixed disc. On passing along the screw at each setting of the indicator in the successive thread the reading is taken on the stationary disc opposite the nearest line on the micrometer disc. The differences of the readings in divisions from the initial reading of "5" give the cumulative error in the pitch at the thread concerned in ten-thousandths of an inch.

Floating Carriage Diameter Measuring Machine. This machine (Fig. 109) has been designed to measure to within 0·0001 in. the full, effective, and core diameters of screw thread plug gauges and similar work, as well as external plain diameters.

The micrometer carriage, having a vee groove and flat face on its under side, moves freely on hardened steel balls resting in two ground and lapped vees in the top face of the intermediate slide. The micrometer carriage has cast brackets at each end, one carrying a micrometer head fitted with a high-precision screw controlled by a large diameter drum graduated to 0·0001 in.

and capable of being read by estimation to 0·00002 in.

To eliminate the personal element in the "feel" of the micrometer, the adjustable anvil of each size is fitted with a mechanical indicator. It consists of a movable anvil which acts against a light spring pressure upon a two-stage system of levers giving a magnification of approximately 350 to 1, a pointer being used in conjunction with a zero line. This means that for an anvil movement of 0·0001 in. the pointer moves 0·035 in.

To measure plain diameters and the full diameters of screws a reading is first taken over the crests of the threads or the plain diameter with the indicator pointer at zero. The work is then replaced by a reference disc or a standard plain plug gauge of known dimensions and a second reading taken.

If the micrometer readings on—

Standard plain plug	R
Over work	R_1
Then full diameter	
F	D + Difference between R and R_1
where D	Size of standard plug
F	Diameter of work.

To determine the effective diameter of a screw thread, thread-measuring cylinders are first located in the thread grooves as shown in Fig. 109. The micrometer is then advanced and a reading taken, after which the screw is replaced by a reference disc or a standard plain cylindrical plug gauge of known dimensions, the effective diameter being calculated from the readings obtained.

Universal Gear Testing Machine. The universal gear testing and measuring machine shown in Fig. 110 permits of testing under a light but constant contact pressure between the gear and a master, the pressure being adapted to suit the size of the work. A sensitive pendulum system is employed, the movement being transmitted to this

FIG. 110 UNIVERSAL GEAR TESTING AND MEASURING MACHINE

system through a lever arm which swings in ball bearings and acts at the extreme outer end of a second lever, whereby the measuring pressure is applied. The pressure can be regulated by means of additional weights, according to the size of the gear to be tested.

The recording device is extremely sensitive. The chart paper is placed on a circular platen which can be easily turned and, since there is practically no pressure between the chart

and the recording pen, the latter is free to record the errors with a high degree of sensitivity.

The machine comprises two concentric tables, one above the other, the upper pendulum table swinging on ball bearings, while the lower table

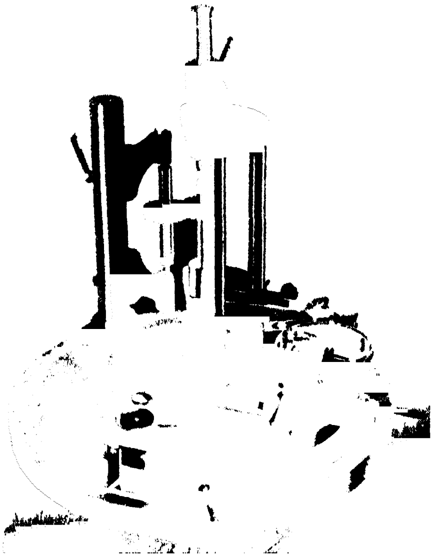


FIG 111 ROLLING TEST OF SMALL SPUR GEARS

is stationary. Weights secured to the under side of the lower table serve to turn the upper table in one direction. The gear to be tested is held on an arbor mounted on the pendulum table and engages with the master gear which is held on the fixed table. If the master gear is slowly turned by hand, the gear to be tested is rotated at a corresponding rate. Tooth errors of the gear due to incorrect involute flank form, eccentricity, or faulty dividing, cause this gear to change its centre distance from the fixed master gear. These changes in the relative position of the gears are indicated on a dial gauge and also recorded on the circular chart which revolves at the same speed as the gear under test. Two concentric tolerance circles showing the plus and minus limits are marked on the paper, and the rolling diagram plotted on the paper will be concentric with the tolerance circles

FIG. 112 INVOLUTE TESTING OF SPUR GEARS

as well as within the limits thereof if the gear is free from errors. The magnification or ratio of leverage at which the errors are transferred to the recording pen may be 50 to 1, or 100 to 1, or 250 to 1, depending on requirements. The correct distance between the centres can be adjusted by means of precision gauge blocks and a micrometer dial. The machine is suitable for testing spur gears (Figs. 111 and 112) or helical gears (as in Fig. 110) and worm gears, various interchangeable attachments being available. These latter also include an attachment for testing milling cutters, and indexing plates for circular pitch.

Bevel Gear Testing Machine. A somewhat similar machine to the aforementioned, shown in Fig. 113, is used for testing bevel gears. The lower circular table is stationary and carries one of the gears to be tested, while the other gear is mounted on a beam which can be pivoted about the axis of the table, which coincides with the vertex of the gear cone. The beam swings on ball bearings, the contact pressure between the two gears being varied by weights, as in the case of the previous machine. The amounts of the total errors are read from a dial gauge and can be recorded on a chart.

Apart from testing the running properties of the gears, the machine also serves to check face angles, deviations from nominal dimensions, and pitch and involute errors. For testing the angle between the axes at which the gears to be tested are rolling in perfect mesh, the lower table is provided with an angular graduation and vernier. Setting up is effected by means of precision gauge blocks which are inserted between reference surfaces on the bevel gear carriers and a reference cylinder mounted concentrically with the cone vertices of the gears. For quantity tests a special attachment is available, employing dial gauges for determining the deviations from the nominal assembly dimensions. Another attachment serves for testing the pitch from tooth to tooth by means of special micrometer indicators. In practice it is found that assembly costs can be reduced and noisy bevel gears eliminated by testing the gears

FIG. 113. DETERMINING THE BUILDING-IN DIMENSIONS IN THE MASS PRODUCTION OF BEVEL GEARS ON A BEVEL GEAR TESTING MACHINE

FIG. 114. AXIAL BEARING PLAY MEASURING INSTRUMENT

previously while rolling in mesh. The rolling diagram shows the total errors of the gears, and practice in reading such diagrams frequently obviates laborious examination of the individual teeth.

The nature of the product will, of course, largely determine the types of instrument to be included in the gauge and tool measuring room. There is a large variety of instruments, two of which, by way of examples, are shown in Figs. 114 and 115.

FIG. 115. HOB TOOTH TESTER

Tool Stores

In the interests of genuine economy as well as of economy in time and labour, and also to ensure system and orderliness, tools and gauges used in the shops should be stored and issued in accordance with a plan which checks both the number and type of tool or gauge, and to whom it is issued. To achieve this, a centralized tool store should be established in every shop. Its advantages are that tools are not duplicated unnecessarily, everyone knows from where to obtain his tools and gauges, the minimum labour is required to store them, and proper care and attention is ensured. Every class of tool should be catered for in this way—milling cutters, reamers, drills, machine arbors, high-speed and tungsten carbide tools. Milling cutters should be hung on stands, every one indexed, and a disc bearing the index number hung on the peg supporting the cutter. Rosebits, cutter bars, and other items should be dealt with in a similar manner. Each type of tool should be kept separate, a distinctive disc corresponding to the particular type being fixed on the stands.

Method of Issuing Tools

A board numbered with the operators' clock numbers and having discs with corresponding numbers should be located on one side of the stores, the method of issuing tools being as follows: When an operator requires a tool, he should quote his clock number and the name of the tool or gauge required to the tool storekeeper, who will go to the board, take from it the disc bearing the operator's clock number, and place it on the hook from which he takes the tool required. The disc containing particulars of the tool should be removed from its hook and placed on the hook bearing the operator's clock number, this ensuring that at any time the tools can be located and traced to an individual, whilst the number and type of tools

issued can be ascertained from the operators' tool issue board. When the tool is returned, the corresponding disc should be removed from the number board in the operator's presence, and placed on its respective peg or stand, together with the tool itself if in good order. The disc bearing the operator's number should be removed from the tool stand and refixed in position on the number board. In the event of the tool requiring sharpening or repair, it should immediately be sent to the tool room, in which case a red disc should be placed on the respective tool peg or stand.

Revolving Tool Rack

The adoption of revolving racks of the type illustrated in Fig. 116 is strongly recommended for extensive use in the tool room stores. They should be constructed of six boards fixed on a central pillar or column, which is fitted with ball thrust bearings to facilitate easy handling of the boards to any desired position. If these boards are made, say, 4 ft 6 in. × 1 ft. 6 in., one rack will give no less than 81 sq. ft. of storage space in a most acceptable and compact form. The boards should be fitted with brackets or hooks as required for locating the drills, gauges, or other tools.

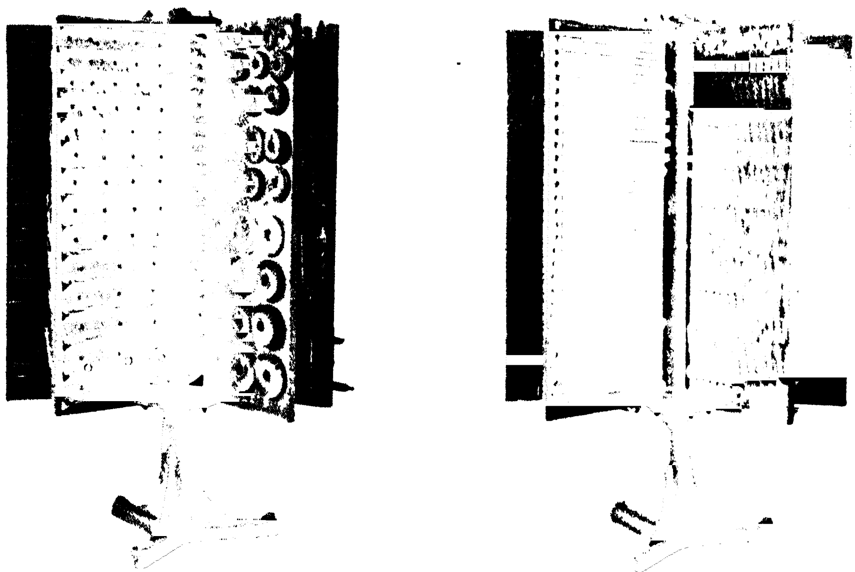
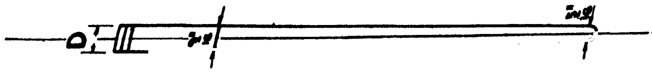
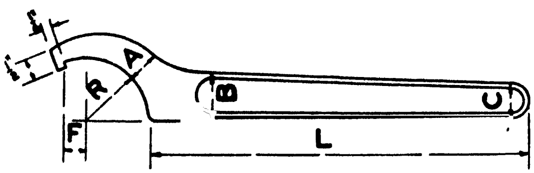


FIG. 116 REVOLVING TOOL RACK

Among the many types of tools handled in the tool stores, twist drills in particular are generally in constant demand, and therefore it is desirable that such a system should be evolved for storing them, the storekeeper thus

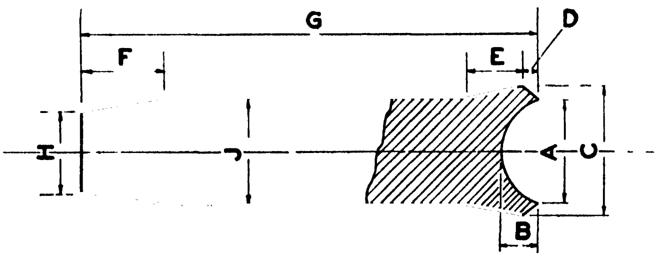
being enabled to issue and receive any size of drill in the minimum of time. *The drills may be grouped in*





R	1 1/16"	1 1/4"	1 7/16"	1 1/2"	1 5/8"	1 3/4"	1 7/8"	2 1/4"
A	1/2"	5/8"	5/8"	5/8"	11/16"	11/16"	11/16"	7/8"
B	3/4"	7/8"	1"	1"	1"	1"	1 1/8"	1 1/8"
C	5/8"	3/4"	7/8"	7/8"	7/8"	7/8"	1"	1"
D	9/16"	5/8"	3/4"	3/4"	3/4"	3/4"	7/8"	7/8"
E	5/16"	7/16"	1/2"	5/8"	5/8"	3/4"	3/4"	3/4"
L	9"	9"	9"	9"	11"	11 1/2"	1' 0"	1' 0"
Jaw	All Jaws to be made to B S I Specification							

FIG. 117. STANDARD CLAW SPANNERS



Size of Rivet	A	B	C	D	E	F	G	H	J
3/8"	5/8"	5/32"	1 1/16"	5/16"	3/4"	—	6"	—	1"
1/2"	3/4"	3/16"	1 1/4"	5/16"	3/4"	1"	6"	7/8"	1"
5/8"	15/16"	7/32"	1 7/16"	5/16"	3/4"	1"	6"	1"	1 1/8"
11/16"	1 3/16"	11/32"	1 5/8"	3/8"	3/4"	1"	6"	1 1/8"	1 1/4"

FIG. 118. STANDARD CUP SNAPS

progressive sizes on the board as follows --

1st Row.	Drills, sizes		1/16 in. to 5/8 in.
2nd ,,	,,	,,	41/64 in. to 61/64 in.
3rd ,,	,,	,,	31/32 in. to 1 17/64 in.
4th ,,	,,	,,	1 9/32 in. to 1 5/8 in.
5th ,,	,,	,,	1 41/64 in. to 2 5/64 in.

The holding capacity of one board will be not less than 100 drills.

Tool Shadow Boards

A shadow board usually takes the *form of a black board on which are painted in white, or some other contrasting colour, the outlines of* the tools, e.g. all classes of spanners, which the board carries. If a tool is missing it can readily be seen of what type it is. The ever widely increasing adoption of tool shadow boards, not only in the tool room but in all parts of the factory, testifies to their practical utility. It is indeed an admirable practice to place a shadow board alongside each machine, and in those factories where this is done there is a noticeable tendency towards economy in tools, as well as tidiness in the shop. Where desired the boards may be arranged in the form of cabinets, with doors of diamond-shaped wire mesh.

Tool Charts

There is much to be said in favour of providing framed tool charts in the tool room. Fig. 117 shows a claw spanner, whilst Fig. 118 shows a cup snap for forming rivet heads with a pneumatic hammer. This practice tends to eliminate the necessity for any tools being "made to pattern."

CHAPTER IX

JIGS AND FIXTURES

Differentiation between Jig and Fixture

THERE is, and always has been, a great diversity of opinion among engineers as to the relative meaning of the terms jig and fixture, and consequently one reads various definitions and explanations of them. It will be as well to note the accepted definition.

It can be said that a jig is a contrivance which is generally attached to the work to be machined, and takes the minimum of time to locate or to be attached to any particular job. The term jig is usually associated with contrivances used on drilling, milling, and boring machines.

On the other hand there are two types of fixtures. The first is attached to a machine for the purpose of a particular operation and becomes for the time being an integral part of the machine. It takes a much longer time to locate than a jig but this does not mean that the original lines of the machine have been altered; the machine has only been supplemented. If, however, the appearance and working parts of the machine have been permanently altered so as to bear no resemblance to the original, it is neither a jig nor a fixture, but an entirely new machine.

The other form of fixture is not associated with machines. It is used to facilitate assembly operations, and at the same time to ensure interchangeability of the assembled parts. Such fixtures are increasingly and extensively used. In some instances it is necessary to change the position of details which are being assembled and provision is frequently made for the fixture to be revolved and set in any desired position whilst the details are still located within it, the utilization of ball thrust races making this a comparatively simple task even for heavy components (Fig. 19, Chapter III). Wherever fabricated details are being prepared, the use of a fixture would appear to be indispensable, yet it does not follow that it is necessary always to design a fixture specially for what may be only a limited number of items. Temporary modifications can often be made to a standard fixture thus permitting of a still wider range of work.

Many instances arise where a jig and fixture are used in conjunction with each other, and sometimes it is extremely difficult to say where one begins and the other finishes.

Jigs and fixtures are only synonymous inasmuch as they are both designed to facilitate machining and other operations, and to reproduce multiple parts accurately and cheaply. It is generally conceded that in factories where jigs and fixtures are the rule and not the exception, machine setting-up is reduced to the lowest possible time. Another point is

that if a jig or fixture has been properly designed, it is frequently possible to employ a semi-skilled operator who will perform the same work with as much accuracy as would a fully rated craftsman working under the same conditions.

Advantages of Jigs and Fixtures

The outstanding advantages to be derived from the use of jigs and fixtures can broadly be described as follows--

(1) Accuracy and interchangeability of details are ensured.

(2) Production is cheapened.

(3) It is frequently possible to use a less skilled operator on manufacturing and production work.

(4) Fitting is eliminated and the introduction of assembling methods is effected.

Such disadvantages as do exist may be summed up briefly in the following—

(1) The use of jigs and fixtures does not encourage individual ingenuity, skill or resource, except for those few who are engaged in their manufacture.

(2) To take full advantage of jig and fixture methods additional overhead expenses are incurred, as it is essential to employ men who have had a specialized training in their design.

(3) Unless the jigs and fixtures are designed rightly, the results are likely to be as disastrous as if they were not made correctly.

The advantages of jig and fixture work over that done under ordinary conditions are manifold. For instance, with a radial drilling machine, by using a hardened steel bushed jig it is possible to drill through an almost unlimited number of pieces of plate with the certainty that the position and size of the holes will be as correct as possible. No marking out is necessary and no clamping, as when the jig itself is clamped, especially in cases of box, angle, and frame jigs, it is only necessary to drop the work into its proper position and run the drill through. It is impossible for the operator to pick up a larger size drill and inadvertently use it for the job, as it would not go into the hardened bushing. This in itself is a check.

Points in Design

The first point to be considered is the prime cost of a jig or fixture in relation to the number of pieces to be machined or assembled. It sometimes occurs that, although the pieces to be machined are numerous enough, a detailed estimate of the proposed jig shows that the cost of making and maintaining it would exceed the profits of a quicker and cheaper output, and the outlay would not be justified. In such a case, to make a jig would be a waste of time and money. Another point is its intrinsic value. It is not only the actual time and money that the use of a jig or fixture saves on any particular job which makes it a good investment, but the fact that, by using it, the time saved will allow a machine to be earning money on other work. There is no doubt that work performed by the use of jigs and fixtures, besides being more accurate, is done in the majority of cases in appreciably less time than would otherwise be taken.

With jigs and fixtures, as with everything else appertaining to engineering, the design is fundamentally important. Every part should be designed with great deliberation and thought, and particular attention given to details. There is no need, however, for unnecessary elaboration causing needless expense. Again, the general workmanship and finish require to be of the very best character, every possible care and precaution being taken to ensure the maximum amount of accuracy and efficiency and the minimum amount of expenditure. Where the manufacture of jigs and fixtures is more or less continuous, the purchase of a jig boring machine will be fully justified.

To summarize, the chief points are simplicity of construction, cheapness, durability, lightness, accuracy, facility for handling, and, above all, reliability.

Preliminary Analysis

Whenever the introduction of a jig or fixture is contemplated, it is of great advantage to provide an answer to each of the following questions. Where the word jig occurs, it will be appreciated that, in many instances, the term fixture is also applicable.

(1) Does the job need a special device?

(2) Is the job likely to recur?

(3) What is the time expected to be saved by designing a special appliance, and will this saving compensate for the outlay? What allowance is necessary for maintenance?

(4) Can the jig be so designed that, while the machine is working on one piece, the operator can be setting up a second, third, or fourth piece, and, if so, will the extra cost involved be more than covered by the time and money saved?

(5) Is it better for the work to go on the jig, or the reverse, supposing either way is possible?

(6) How light and portable can the jig be made without reducing its strength?

(7) Will the locating of the jig occupy so much time that the machine will long remain idle, and, if so, will this loss of time be compensated for by that saved in machining?

(8) Will the cuttings or borings made during machining operations so clog and foul the jig as to render its clearance a frequent and/or lengthy operation before further details can be inserted? What arrangements can be made to prevent this clogging, or, if not preventable, to allow the cuttings to be removed with the least possible delay?

(9) Are ample provisions being made to ensure the cutting compound reaching the point of the cutter easily?

(10) Will it be cheaper to do the job without any special appliance, having regard to the time taken with and without a jig, as well as to the cost of making and maintenance of the latter?

There are, of course, many other points to be considered in jig and fixture design. Both jigs and fixtures should always be made strong enough to enable the machine on which they are to be used to be worked to its utmost capacity, without there being any danger of their breaking or becoming distorted.

It should be appreciated that machining time is not nearly so important as "floor to floor" time, and it is in this latter connection that correctly designed jigs and fixtures can materially assist in ensuring that "floor to floor" time is the minimum possible. Another important point is to construct the jig in such a manner

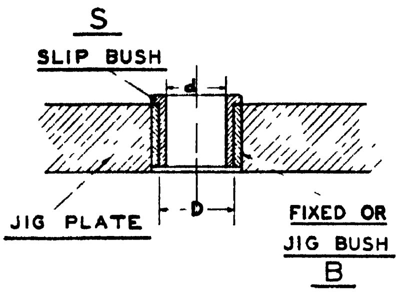


FIG. 119. SLIP BUSH FOR DRILLING JIG

that it is impossible for the operator to make a mistake by placing the work in the wrong position. This mistake can and does sometimes happen, and is generally due to bad design.

"Don'ts" for Jig Designers

(1) Don't attempt to make a jig before you have studied it thoroughly from every possible point of view—feasibility, utility, practicability, and cost in relation to the job for which it is intended.

(2) Don't elaborate. The simpler it is the better.

(3) Don't make a single jig if it is possible to utilize a double one.

(4) Don't make your bushings so shallow that the drill or cutter is not properly guided. Much unsatisfactory work arises from this cause.

(5) Don't forget to provide facilities for the chips to fall clear or be easily removed.

(6) Don't forget to make adequate provision for flooding the tool point with compound. It saves constant re-grinding.

(7) Don't make a jig unnecessarily heavy or unnecessarily light. Both are wrong.

(8) Don't forget to make your jig "fool proof." Inattention to this important detail may lead to disastrous results.

Slip Bushes

The use of hardened slip bushes, illustrated in Fig. 119, frequently avoids the necessity of having more than one drilling jig of a similar type. If a smaller hole is required than the usual one *D* for which the jig is designed, then all that is necessary is to insert temporarily a slip bush *S* into the permanent bushing *B*, to give the size of hole *d* desired. On the other hand, if the smaller size of hole *d* is generally needed, but occasionally the larger hole *D* is needed, the jig should still be designed to take the slip bush *S*. This latter will then be used for normal working, but when the larger hole *D* is necessary the slip bush will be removed and the drill inserted through the hole of the hardened fixed bush *B*. Slip bushes should be a good push fit, and as far as possible should have standard proportions.

Practical Examples

It will be helpful to give a few examples of jigs and fixtures which have occurred in recent practice.

Drilling Jig. Fig. 120 shows a double vee-block jig for drilling cotter holes in round bars and pins on a

sensitive drilling machine. The two vee-blocks, *A* and *B*, can be moved along the circular mandrel *C* and locked in the desired position by the set screws *D* and *E*. The endplate *F* provides a stop for the work piece if required and also serves as a handle for steadying the jig when the actual drilling is being performed. In some

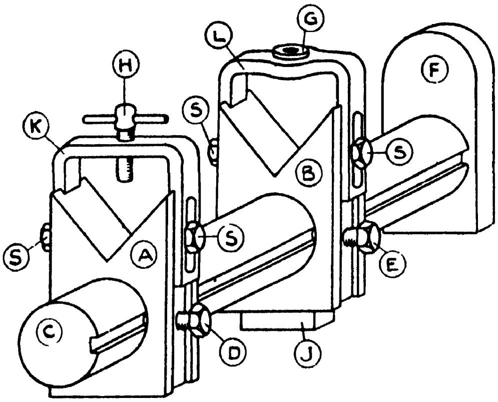


FIG. 120. DOUBLE VEE-BLOCK DRILLING JIG

cases the head of the pin is made to abut on the outer face of the vee-block *A* instead of using the endplate as a stop, but in either case the position of the vee-block *B*, and hence the drill guide *G*, ensures the cotter hole being drilled in the correct position. The work piece is clamped down by the thumb-screw *H*. To prevent rotation of the jig by the drill a spigot *J* is provided which engages with a slot in the drill table. This jig is suitable for work of various diameters within a limited range, such as from $\frac{3}{4}$ in. diameter to $1\frac{1}{2}$ in. diameter. For the extreme diameters compensation is provided by the stirrups *K* and *L* being moved vertically in their slides and locked by the four set-screws *S*.

Box Drilling Jig. Fig. 121 shows diagrammatically a principle which can be applied in the use of a box

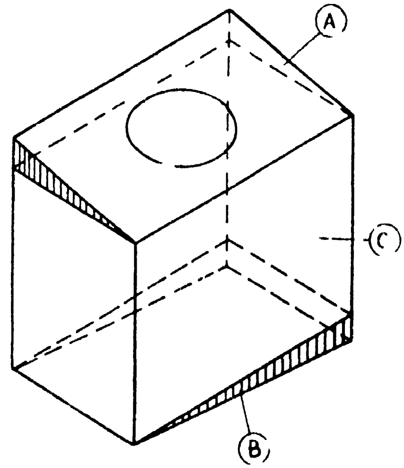


FIG. 121 APPLICATION OF BOX DRILLING JIG

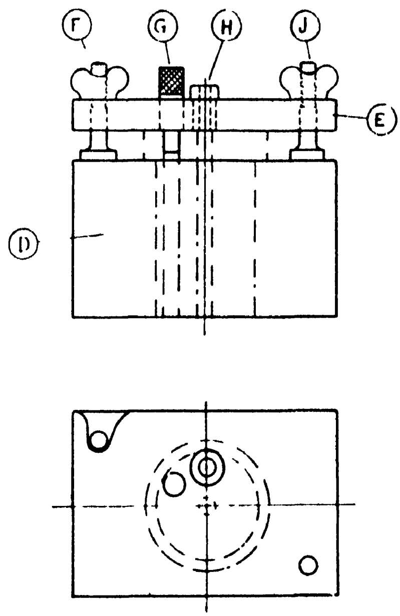


FIG 122. ELEVATION AND PLAN OF BOX DRILLING JIG

drilling jig (a plan and elevation of which are illustrated in Fig. 122) in order to drill at various angles. The

box jig is used for the insertion of the circular grooves, *M*, in the six-roller tube expander cage, *K*, shown in Fig. 123. The expander cage is in the condition shown in Fig. 124 when the grooving is commenced in the box jig.

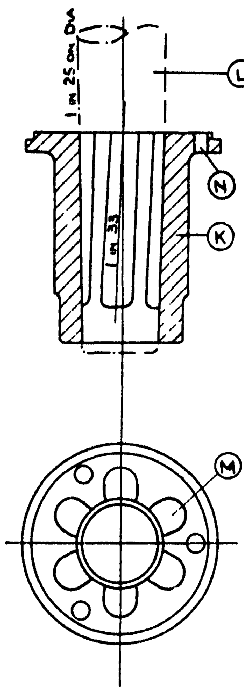


Fig. 123. Six-roller Tube Expander Cage

Referring again to Fig. 121, it should be noted that the top *A* and the bottom *B* are both inclined, the bottom *B* being a "loose" piece which is attached to the block *C* for the second series of operations. The sloping top *A* gives the feed to the rollers, whilst the sloping bottom piece *B* allows for the tapered plane of the rollers. In this instance the grooves have a lead angle of 1 in 33 (right-hand) whilst the rollers are tapered 1 in 36. The mandrel *L* and the bore of the cage are both tapered 1 in 25, and the largest end of the rollers is remote from the end of the cage at which the mandrel is inserted.

Referring now to Fig. 122, the expander cage, shown by chain-dotted lines, is placed in the box drilling jig *D* and locked in position by means of the swinging locking plate *E*, and the two wing-nuts *F* and *J*. After the first groove hole in the cage has been drilled through the hardened drill guide *H*, the wing-nuts on the studs

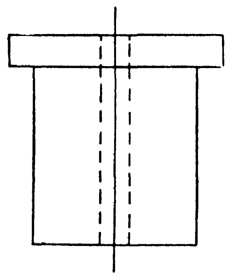


Fig. 124. Expander Cage, before Grooving in Box Drilling Jig

F and *J* are unscrewed and the locking plate swung back. The expander cage is then moved round so that the locating peg *G* will drop into the hole drilled in the cage. The operations previously described are now repeated and the second hole is drilled in the cage, the correct pitch of the holes being ensured by the relative positions of the drill guide *H* and the locating peg *G*. The remaining four holes are drilled by repeating the operations described.

The second series of operations is carried out in a similar manner. The loose bottom piece *B* is fitted and, using the same drill as before, the grooves are tapered slightly in order to accommodate the tapered rollers.

It will be appreciated that the "lead" angle of 1 in 33 is maintained when the loose bottom piece is fitted, but the drilling runs towards the centre of the cage and by doing so makes the groove larger at the bottom than at the top of the cage. The bore for the mandrel is provided after the six roller grooves have been completed. Three small grub-screws N fasten the cap (not shown) to the expander cage and so keep the rollers in position.

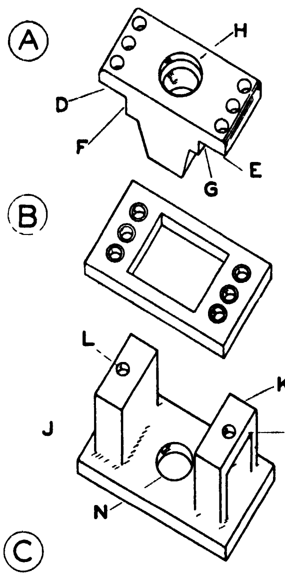


FIG. 125. DRILLING JIG PLATE AND COMBINED JIG AND FIXTURE

Combined Jig and Fixture. Fig. 125 shows a drilling jig plate and a combined jig and fixture for drilling and boring the guide casting A, on which the marking out is entirely eliminated. After the casting has been planed on the faces D, E, F, and G, it is placed on the drilling table in an inverted position and the jig plate B is dropped on to the faces D and E. The six outer holes are then drilled. The final operation is to bore and counter-bore the hole H, and the combined jig and fixture C is used for this purpose. The casting is placed on the fixture so that the faces D and E rest on the top of pillars J and K, and locating pins are then passed through the middle outer holes of the casting and the holes L and M. The hole N acts as a seat for the boring bar guide bush.

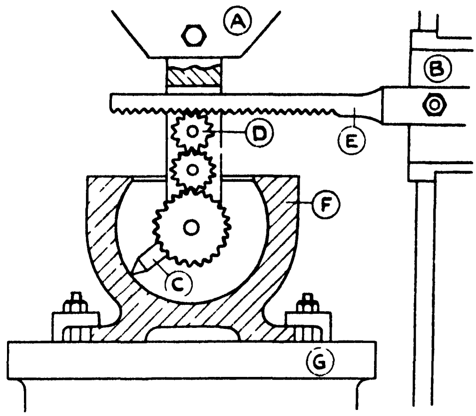


FIG. 126. SPHERICAL INTERNAL BORING FIXTURE

Internal Boring Fixture. Fig. 126 shows a fixture in the form of a spherical internal boring attachment as applied to a vertical boring machine. The machine has two heads—A, capable of vertical feed, and B, capable of horizontal feed. The rotation of the tool C, for spherical boring, is achieved by means of a train of pinions the uppermost of which, D, is rotated by the rack E. The article operated upon, F, is clamped to the table G which rotates in the usual manner. To produce spherical boring the head A is kept stationary while the head B is fed horizontally.

Templets

A templet generally takes the form of a flat piece of sheet metal or plate of a thickness and size suitable for the work in hand, and is cut to the required profile. Templets are extensively used in the smithy for the guidance of the smith; in the machine shop to eliminate the costly hand operation of marking out; and on

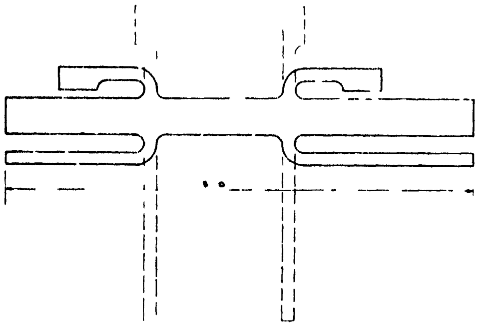


Fig. 127. Burning out Templet for Shaft

oxy-acetylene and oxy-coal-gas burning out machines where the templet is used as a former, along the edge of which an electro-magnet runs with the burner following the same path whilst operating on the billet or plate.

Sometimes, as in the example shown, Fig. 127, a templet is used to great advantage in conjunction with a burning out machine to permit of a smaller billet of material being used and to reduce the amount of smithing necessary. The illustration shows a shaft with two arms, the billet from which the shaft was made being originally of rectangular shape. The full lines show the contour obtained on the burning out machine by the use of the templet, and the chain-dotted lines show the shaft after the arms have been "drawn out" in the smith shop to the position required.

Former Plates

Milling machines in particular make extensive use of former plates. These former plates, which are cut to the profile of the component to be milled, are securely clamped to the machine

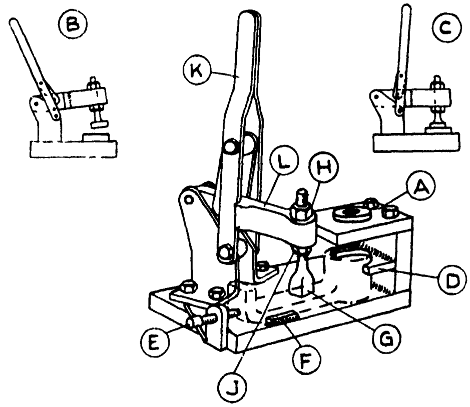


Fig. 128. Rapid Acting Toggle Clamp

table and arranged to direct the tool holder as required.

Rapid Acting Toggle Clamp

There are many well-known types of clamp in use, though perhaps none which has a greater application than the rapid acting toggle clamp illustrated in Fig. 128. This particular example is designed to deal with a specific work piece. With the clamp is combined a detachable drill guide *A*. The principle of the rapid acting clamp is shown in views *B* and *C*. In the main view the work piece, which is a lever with thick boss and cranked arm, is shown chain dotted. Before clamping, the work is forced against a bed

piece *D* by the thumb-screw *E*. Rotation of the work is prevented by two stops, one of which is shown and marked *F*. To obtain a clamping effect of adequate power without the need for applying excessive force on the handle *K*, it is necessary to adjust the height of the clamping head *G* by means of the nuts *H* and *J*. An easy pull of the handle quickly raises the clamping bar *L* clear of the work. The clamping device itself may be removed from the bedplate as a unit and may then be applied to another fixture if desired.

Handling of Jigs and Fixtures

Too much stress cannot be placed on the handling of jigs and fixtures, this being quite as important as designing them. It is perhaps especially noticeable in the case of drilling jigs, where there is a number of bushings. As soon as it is noticed that the bushings have become worn through constant use, and this always happens eventually (chiefly through the chips passing up the grooves of the cutter and rubbing against the bushing sides), the bushings should be changed. If this is not done, the cutters or drills can move from side to side and possibly ruin what, with a little care and forethought, would have been a perfect job. It is a good plan, in the case of jigs and fixtures in constant use, to keep a number of spare bushings handy for immediate replacement.

Another important point is cleanliness. It does not matter how good and accurate a jig may be, its accuracy will be greatly impaired if it is allowed to get dirty and remain so, chiefly from an accumulation of grit and cuttings. This is especially noticeable in the case of jigs used on cast iron. The fine dust, if allowed to accumulate, very quickly solidifies, and work that should sit squarely on the set provided for it does not do so, with the result that it may have to be scrapped as unsuitable, resulting in loss of time, labour, and material. This is one of the most frequent causes of failure, and the mistake is not usually discovered until the job gets to the hands of the erector. Only those who have had the misfortune to experience these things can fully realize the endless trouble caused by such carelessness. All jigs should be given a distinctive number and a register maintained for them. On the completion of a job they should be returned to the stores to be overhauled and thoroughly cleaned.

CHAPTER X

PERSONNEL

THERE are, in the British Isles, over six million people employed in industry, this number representing one-seventh of the total population. Of these, some four million are men and boys and the remainder women and girls, giving a proportion of 2 to 1. If we classify factories into seven categories, according to the number of employees, we get the approximate figures given in Table XIII.

Whilst it may be possible to standardize machines and equipment within the factory, there would appear to be no such possibility when the human element is under consideration. For this reason alone the personnel department must always be organized on sound lines.

Functions of Personnel Department

The chief functions of a personnel department are tenfold. They are—

(1) To draw up the conditions of employment, rates of pay, and superannuation schemes.

(2) To fill vacancies as and when they arise, to arrange transfers and to control staff reorganization schemes.

(3) To maintain all staff records and compile statistics relevant to the entire personnel of the factory.

(4) To be thoroughly conversant with the requirements of the Factories Act, National Health Insurance Act, Unemployment Insurance Act, and Workmen's Compensation Act, and to put the regulations of these various Acts into operation.

(5) To register agreements with trades unions and ensure that they are honoured.

(6) To record the business transacted at meetings of works and shops committees.

TABLE XIII

CLASSIFICATION OF FACTORIES IN GREAT BRITAIN ACCORDING TO NUMBERS ENGAGED

Size Group	No. of Employees in Factory	No. of Factories	No. Employed Expressed as a Percentage of Total No. in Industry
1	1-25	110,000	13
2	26-50	13,000	8
3	51-100	9,000	11
4	101-250	8,000	20
5	251-500	3,000	16
6	501-1,000	1,000	13
7	1,001 and upwards	600	19
TOTAL . .		144,600	100

(7) To prepare and issue all instructions and circulars relevant to the staff, e.g. disciplinary scheme and educational courses.

(8) To provide amenities for the staff.

(9) To stimulate welfare work and regulate works' benevolent funds, voluntary collections and charity appeals.

(10) To deal with accidents and take precautions against them.

The control of the personnel department should be vested in an officer

who is well versed in human nature, who combines resolution with impartiality and fairness, and who whilst being tactful and considerate always acts in the best interests of his firm without causing offence. He must give emphasis to these qualities by his actions, thus encouraging his staff to act similarly.

Conditions of Employment

The general conditions applicable to all employees, regardless of grade, will require to be drawn up on the lines of the following -

(1) The name and address of each employee must be recorded in the office or shop to which he is attached, and any change of address must be at once notified.

(2) Employees must attend at such hours as may be required, pay prompt obedience to persons placed in authority over them, conform to all the rules and regulations enforced by the firm, and must not engage in trade apart from their regular employment with the firm.

(3) Every employee must assist in carrying out the rules and regulations of the firm, and must immediately report to his superior officer any infringement thereof, or any occurrence which may come under his notice affecting safe and proper working.

(4) Any employee may, from time to time, be required to undergo medical, practical, or educational examinations in accordance with the regulations in force.

(5) Employees absenting themselves from duty for more than one day from any cause whatever must notify their superior officer, stating the reason of their absence. In the event of such notice or doctor's certificate not being received on the third morning of absence these employees may be considered as having left the employment of the firm.

(6) Employees must, if required, make good any article provided by the firm when damaged by improper use on their part.

(7) Employees must not—

(*a*) appropriate to their own use any property of the firm.

(*b*) waste or wantonly destroy stationery, stores, or any other property of the firm.

(8) Tools or any articles for private use are not allowed to be made in the workshops.

(9) The firm may at any time-

(*a*) dismiss without notice, or

(*b*) suspend from duty and, after inquiry, dismiss without notice, or

(*c*) suspend from duty as a disciplinary measure an employee of the firm for any one or more of the following offences, viz.

(i) being in possession of or under the influence of intoxicating liquors whilst on duty.

(ii) disobedience of orders.

(iii) misconduct or negligence

(iv) absence from duty without leave.

An employee so dismissed forfeits any right to notice and also any right to wages for any period subsequent to the completed week preceding his dismissal, or preceding his suspension from duty prior to dismissal, as the case may be.

(10) No employee shall expose himself to danger, and he must prevent as far as possible such exposure on the part of other employees and spare no opportunity of warning those who neglect to take proper care.

Reckless exposure of himself or others to danger, on the part of any employee, is an offence against the rules of the firm, and will be dealt with accordingly.

In addition to these general rules, there may be many conditions of service applicable to particular grades. A copy of all the rules and conditions of service should be handed to every employee upon engagement, a certificate of acceptance being obtained on the lines of the following –

> I hereby acknowledge that I have been supplied with a copy of the rules of the firm, and do hereby undertake to abide by the said rules in every respect, and all other rules and regulations that may from time to time be issued for the guidance of the firm's employees.
>
> Signature of employee
>
> Date 19

Rates of Pay

A base rate is the flat rate of pay applicable to a grade and is independent of any bonus which may be

earned. In the case of manual workers base rates are generally agreed between the respective trades unions and the employers' federations. There are various rates for each grade in different parts of the country, these differences being due to the influence of both local and national agreements. Whenever a rate is in dispute and agreement cannot be reached between the parties concerned, the matter is referred to the Industrial Court for an independent decision.

It is a common practice to apply a differential rate of pay to certain grades of operators. In the case of a craftsman it may be due to his work being more arduous, or of a better class than that of the average man in his grade. With some grades a differential rate of, say, 1s. is applied after the first twelve months' service in the particular grade, an increase which may be repeated at the end of the second and even the third year.

Chargemen's Differential Rates. A chargeman is a shop employee who controls a number of men, but does not usually enjoy staff status. By way of a basis, a scale such as the following might be considered equitable for him.

STAFF CONTROLLED	DIFFERENTIAL
5 or less	1s.
6 to 10	2s.
11 to 15	3s.
16 to 25	4s.
26 to 40	5s.
Over 40	6s.

An interesting point arises in connection with chargemen's differentials. It is possible to have a chargeman, controlling only half a dozen men, who is required to use considerable ingenuity in the execution of his duties, whereas another chargeman in exactly the same grade, who is controlling fifteen men on work of a straightforward and routine character, is receiving more money. Again, there are chargemen whose daily duties unavoidably embrace initial examination as well as finished work inspection. Such men are clearly in a position to spend a firm's money wastefully without anyone being the wiser. Having regard to such cases, to assess the relative value of a chargeman merely according to the number of men controlled is not entirely satisfactory. It would be perfectly logical, therefore, to introduce a "degree of responsibility" factor, which is distinct and separate from the number of men controlled. To facilitate the application of this, only one factor, equal, say, to 1·5, should be applied in those special cases which are considered to merit it. This would mean that, in the event of a chargeman controlling ten men, for which the normal differential is 2s., this amount would be multiplied by 1·5 if the chargeman's responsibility warranted it, thus giving a differential of 3s.

Cost of Living Bonus. The "cost of living" bonus must not be confused with premium bonus hours or piecework balance, a full explanation of which is given in Chapter XIX. It is a fixed allowance subject to periodic alteration and, like the base rate, payment is made according to the hours worked (or equivalent hours worked), e.g. if the "cost of living" bonus is 10s. per week for an operator who normally works 47 hours, and the

DAY SHIFT

Ordinary Time	*Overtime*	*Extra for Overtime*	*Total*		s.	d.
Hrs.	Hrs.	Hrs.	Hrs.			
47	2	½	49½	@ 47s (Base rate) . . .	49	6
			49½	@ 10s. (Cost of living bonus)	10	6
					60	0

NIGHT SHIFT

Ordinary Time	*Overtime*	*Extra for Night Duty*	*Total*		s.	d.
Hrs.	Hrs.	Hrs.	Hrs.			
45		15	60	@ 47s. (Base rate) . . .	60	0
			60	@ 10s. (Cost of living bonus)	12	9
					72	9

operator only works half the week, he will receive 5s. This amount is not added to the base rate in computing the piecework balance to be paid. Above are shown two examples of weekly wages received on the assumption that in each instance the operator has a base rate of 47s. for a 47-hour week, i.e. 1s. per hour, irrespective of piecework balance, plus 10s. "cost of living" bonus for 47 hours. Overtime on the day shift is assumed to be paid at time-and-a-quarter, and on the night shift at time-and-a-third.

Problems of the Working Week

The working week is a contentious question which is liable to be brought up periodically for revision. It will, therefore, be interesting to show the major problems confronting the employer in such circumstances. Take the case of a factory where the employees are at present working 47 hours per week and where they have made a request for a shorter week of 40 hours. The following will probably constitute some of the employer's self-imposed questions and answers-

QUESTION	ANSWER
To what extent were the standard weekly hours reduced at the end of the Great War?	The hours were altered from 54 hours to 47 hours per week.
By what percentage were time rates per week concurrently increased?	None of the weekly rates was altered. Accordingly the rates per hour were increased by 15 per cent in the case of employees not paid by results. (The 15 per cent is obtained as follows: $\frac{54}{47}$ = 115 per cent.)
By what percentage were piece rates concurrently increased?	*If piecework.* Existing piecework prices were not altered, but new prices were of necessity higher by comparison to the extent of 15 per cent. *If premium bonus.* The basis times were not altered, hence there was an increased cost of 15 per cent on the hourly rate of working.

Question	Answer
What effect had these changes on hourly output of time workers?	It is considered that in the case of time workers the firm lost 7 hours per full working week for every one in that category, except in those few cases where they were of necessity obliged to complete their work week by week.
What effect did these changes have on hourly output of pieceworkers? How far did pieceworkers, particularly where piece rates were not increased, speed up work and maintain their previous output in order to maintain their previous earnings?	Pieceworkers speeded up their work enabling them to earn almost the same amount of wages per week.
If a 40-hour week were adopted or, in the case of continuous shift industries, a shorter shift, could the present output be maintained?	Yes, with additional staff, amounting to $\frac{7}{40}$ of the present staff.
What extra percentage of timeworkers would be required to maintain present output?	Practically the whole of the staff is working on payment by results, therefore the number of additional timeworkers required would probably be confined to the maintenance staff, and would represent 1 per cent of the total staff.
Assuming the maintenance of the present output by taking on the additional employees, would it be technically and administratively possible, quite apart from questions of extra cost, to adopt shorter daily hours?	Yes. It would be necessary to adjust the present working day of 8 hr. 30 min., i.e. 8 a.m. to 12.30 p.m. and 1.30 p.m. to 5.30 p.m. (Saturday 8 a.m. to 12.30 p.m.), to 8 hours per working day, i.e. 8 a.m. to 12.30 p.m. and 1.30 p.m. to 5 p.m. with no Saturday working.
What percentage increase of wages cost would be involved if time rates per hour worked and piece rates were not increased?	There would be no change in the wage bill as the present output could be ensured by introducing more men whose wage bill would balance the lost time of those already in employment, e.g. if 1000 men working 40 hours per week give a certain output, then there is no increase in wages paid, providing the hourly rates are not changed, if the same output is obtained by working 2000 men 20 hours per week.
What percentage increase of wages cost would be involved if time rates per hour worked and piece rates were increased in proportion to the reduction of hours?	An increase of $\frac{7}{40}$ which equals 17·5 per cent.
What percentage increase in social charges, voluntary pensions schemes contributions, etc., would be involved?	If National Insurance and Unemployment Benefit schemes are to be regarded as social charges then there would be an increase of 1s. 7d. per adult worker taken on as additional staff, and in the aggregate this is equivalent to 17·5 per cent increase in social charges.
What would be the effect, expressed as a percentage, on running costs, e.g. fuel, power, and light?	It is not considered there would be any appreciable change in running costs except where an additional shift was instituted. The additional costs incurred by this

Question	Answer
	latter, however, would be partially nullified, particularly with regard to lighting, by employees on the day shift finishing work at 5 p.m. instead of 5.30 p.m.
Would there be a tendency for any increased cost of production to lead to further mechanization and rationalization in order to neutralize the increased cost and so reduce the number employed?	Progressive schemes are continually being initiated, and these would definitely tend to neutralize the increased cost by reducing the number of employees. In certain work the introduction of cheaper material would cheapen the manufacturing costs without effecting any reduction in staff. In the event of there being an increase in the cost of production there would be no greater tendency for mechanization, as it is considered that no more could be done in this direction than is being done at the present time.

Selection of Staff

In choosing a new employee the personnel department is governed by two considerations: (1) that of finding the individual most suitable for the work, and (2) that of securing an individual who is likely to remain with the firm and so help decrease the losses due to too big a labour turnover—losses which are not always appreciated as they should be.

If a candidate for any position which has become vacant, or is shortly to become vacant, has been attracted by an advertisement in the daily Press or in technical journals, by personal contact with another employee who is aware of the vacancy, or if he is recommended by the University Appointments Board, there remains only one satisfactory method of selection after all the preliminaries have been settled. This method is by interview —the acid test which has no counterpart if it can be rightly assumed that the interviewer knows his job.

For any vacant minor position which occurs in the shops, it is possible to draw up a standard application form. This should include name, age, and address, also such particulars as period of apprenticeship and where served, subsequent positions held, technical training received, certificates obtained, and health record. A suggested form is illustrated in Fig. 129. When these forms have been completed, giving all the essential information, the interviewer should compare and contrast those of the different applicants, after which he should arrange to see in turn those whom he considers are the more likely candidates.

Interviewing an Applicant. The personnel department has to exercise great tact not only in the method of selection of candidates for employment, by ascertaining from the candidate those points which are essential for consideration, but in the method of rejection of unsuitable applicants so as not to create any ill-will towards the firm. There can be no standard method of interviewing. Each

APPLICATION FOR EMPLOYMENT AS A TRADE APPRENTICE

(To be filled up in applicant's own handwriting.)

Applicant's Full Name

Full Address

Age Years Born Height without boots

Full name, address and occupation of parent or guardian

Schools attended and length of time at each

Particulars of studies, examinations, and certificates obtained—

Is your health good? Is your sight good?

Is your hearing good?

Have you ever been injured, subject to fits, or operated upon?

If so, state when and give particulars

Have you any bodily defect or infirmity?

If not at school, state how occupied since leaving

Personal Reference.

Give name and full address of someone who has known you for at least 12 months to the present time, and who would answer inquiries regarding your personal character.

N.B. —The name of a relative cannot be accepted.

Applicant's signature Date

FIG. 129. STANDARD APPLICATION FORM (SUITABLE FOR TRADE APPRENTICE APPLICANTS)

candidate must be treated in a different manner, and in a way which seems best to fit the occasion and to reveal those points of character and capability pertinent to the vacancy which has arisen. Important factors which will influence the ultimate selection are the candidate's mental and physical qualities, his personality and appearance, his enthusiasm for the position, and any special qualifications which the interview reveals that he possesses regarding the particular work to be performed.

Trade Apprentice Applicants

Applicants for employment as trade apprentices should show that they are intelligent, have received a good general education, and have a sound knowledge of English, arithmetic, and general subjects. In general, such applicants should only be considered for employment as trade apprentices when they are under 16 years of age. The majority of the boys will usually have to pass through one or other of the various offices in the capacity of utility boys, and as the time spent there may be between nine and twelve months, they will then be able to enter the shops before attaining to 16 years of age, and so obtain the necessary five years' apprenticeship to a particular trade.

Exception to the rule should be made where a boy has attended a central school, in which case he is of necessity a scholarship boy, or where he has attended a secondary school. He has then almost invariably attained to a higher standard of education, and is accordingly likely to prove the better type of employee. The number of such cases, however, is comparatively few, but this rather helps the situation, as it is necessary, by reason of their age, for these boys to go direct into the shops.

Boys who have been previously employed should not generally be considered except in the capacity of machine boys, foundry boys, or equivalent grades, for the following two very good reasons—

(1) They are too old to go into the offices as general utility boys.

(2) Assuming they are paid according to age it is wasteful to pay higher wages to new entrants than is really necessary.

A suggested analysis for computing the suitability of trade apprentice applicants for employment at an interview is appended—

Division	Maximum Points
Arithmetic	12
Algebra	4
Geometry	4
English (reading, writing, spelling)	8
Personality (appearance, manner of address) . . .	40
Mechanical Aptitude (ascertained from hobbies, interests)	12
General Knowledge and Intelligence (geography, history, sport)	20
	100

Typical oral questions should be as follows: How many square feet are there in a square yard? What is 0·125 gall. expressed in pints? What is 8 per cent of £50? What is an acute angle? What is the boiling point of water on the Fahrenheit scale? Correct this sentence, "None of these boys were over 16." In what counties are Dover and Newcastle? What is the capital of Canada? Which is the largest island in the world? For what do the letters F.R.C.S. stand? What are your hobbies? What is the weight of 1 cu. ft. of water? Explain what is meant by the terms "hexagon" and "octagon." Spell the words: Possession; received; acknowledgment; essential; feasible; gauge; questionnaire; encyclopædia; psychology; extempore. Give the date of the Plague of London. How do you ascertain the area of a circle?

If you made a journey round the world along the equator, how many thousand miles would you go? What is the population of Great Britain? For what purpose were the Pyramids built? What is asbestos? Where are the King's keys kept? Who is the British Prime Minister?

Medical Examination

In all cases of new entrants to the firm a medical examination is most desirable immediately prior to employment. It is a necessary safeguard which will undoubtedly prove a good investment. Only the largest of firms will be able to afford the full-time services of a qualified practitioner; others should have a standing arrangement with a reliable doctor. In addition, it is of course a condition of the Factories Act which operates in Great Britain that all young persons starting in a factory shall be required to pass the local factory doctor appointed by the Home Office.

Practical Tests

On the employment of a craftsman there is much to be said in favour of subjecting the candidate to a specific test, e.g. a turner should be asked to measure a diameter by using a micrometer, whilst with some grades, e.g. welders, a periodical standard test should be prescribed and the individual results recorded to ensure that the quality of work performed does not deteriorate.

Testimonials

At least two references of character and ability should be obtained, a questionnaire on the lines of Fig. 130 being addressed to two persons nominated by the applicant. Other questions, some or all of which might be included, are—

(1) Does your knowledge of him extend to the present time?

(2) From what circumstances does your knowledge of him arise?

(3) During the above period were you closely acquainted with him?

(4) Is he married or single?

(5) Is he of British parentage?

(6) Is he, so far as you know, free from pecuniary embarrassment?

(7) Do you consider him qualified to take up the following appointment for which he is a candidate?

(8) Any information which you may have to give respecting his character or qualifications, in addition to what is contained in the answers to the foregoing questions, will be gladly received.

Promotion

The guiding factor in selecting an employee for promotion, apart from age and medical fitness, should be one strictly of merit. It should be universally recognized that a trade apprentice can rise to a high executive position, and that a labourer can rise to the position of highest paid semi-skilled supervisor.

The managerial staff should always be on the alert to notice good men, regardless of grade. In selecting shop supervisory staff craftsmanship alone is not sufficient to justify promotion. Whilst this should be the first essential, personality and technical training are also important. As stated in Chapter I,

(NAME OF FIRM)

(Private and Confidential) 19

Sir,

has applied to this Company for employment and refers me to you as to his Character and Ability. He states he was employed by you from

to

I should be obliged if you would kindly favour me with your replies to the several questions enumerated below.

Yours faithfully,

QUESTIONS	REPLIES
1. How long have you known	
2. In what capacity did you employ him?	
3. What is your opinion of his abilities?	
4. Was he uniformly industrious, sober, and attentive? . .	
5. Have you ever known him guilty of any act of dishonesty or irregularity of conduct? .	
6. When did he enter your service?	
7. When did he leave your service?	
8. Why did he leave your service?	
9. Was he injured at all whilst in your service?	
10. Is he at present or has he been in receipt of an allowance under the Workmen's Compensation Act?	
11. What was his rate of wages when he left your service? . .	
12. Do you know of any reason why he should not be employed by this Company? . . .	

Signature

STAMPED ENVELOPE ENCLOSED FOR REPLY.

FIG. 130. STANDARD PRO FORMA FOR TESTIMONIAL

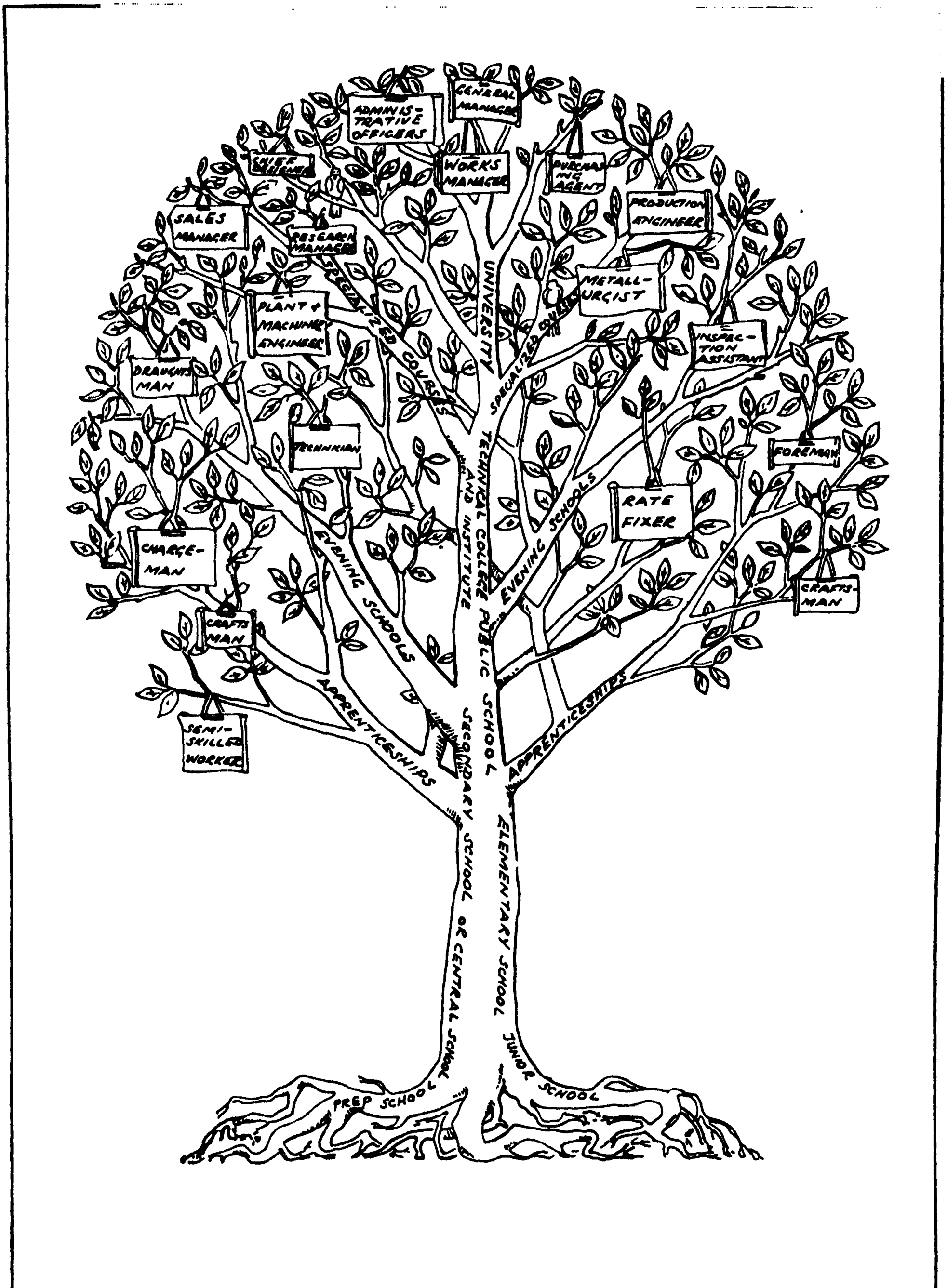


FIG. 131 OUTLOOK OF INDIVIDUAL ACCORDING TO EDUCATION RECEIVED

no one individual can possess outstanding ability in every direction. Candidates should, therefore, be selected on what is considered to be superior all-round ability and knowledge for the immediate vacant position, though it is as well to remember that the selected individual should be capable of fitting into the organization still higher up should an opportunity present itself.

As a general rule it is unsound to transfer an individual from the shops to the offices if he has attained to 35 years of age and has not previously had office experience. It requires many years of administrative experience for anyone to become really efficient as an administrator, and if such training and experience are left too late an individual will, by the time he has proved his worth, be too old to make further advancement in the organization worth while. Thus a key position may be blocked, and if the individual is passed over by one of his assistants some feeling will almost

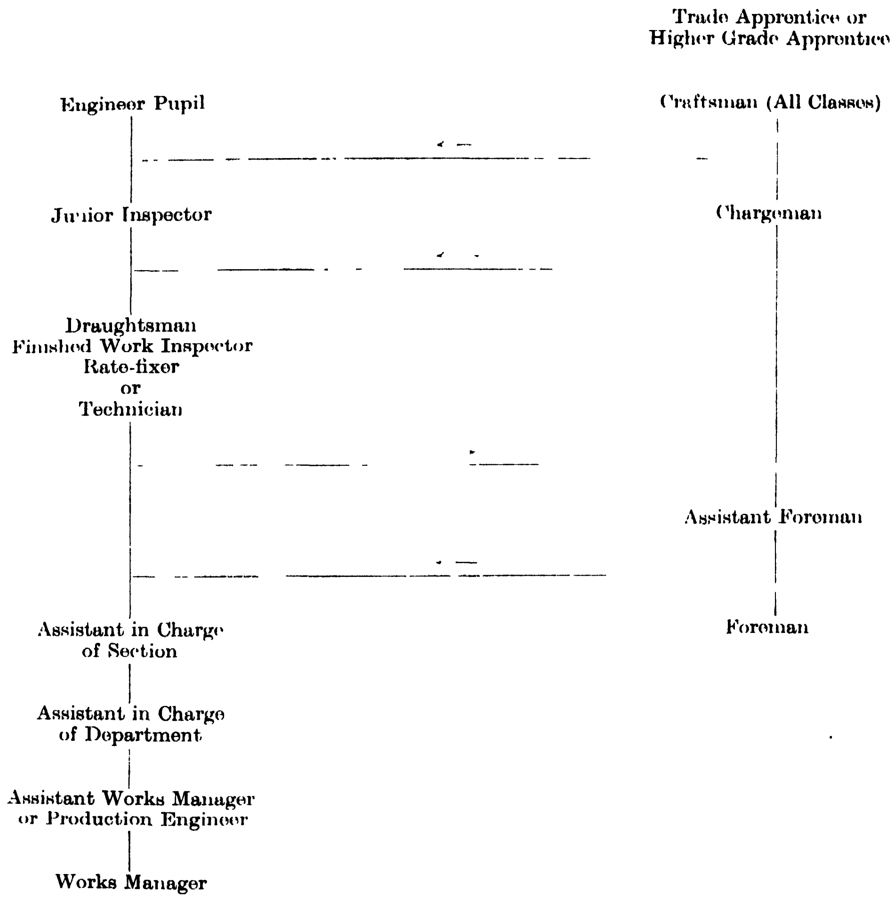


FIG. 132. SUGGESTED LINE OF PROMOTION

certainly be created, with its attendant disadvantages, including of course the disadvantage of the appointee missing valuable experience in the lower position.

Fig. 131 is expressive of what position might be attained according to education, combined of course with personality, and experience. Every endeavour should be made to ensure a spirit of contentment and the best way in which this can be achieved is to establish a definite promotion scheme. Such a scheme, covering specific grades, is outlined in Fig. 132. Similarly, Fig. 133 shows the manner in which relevant information covering a number of possible candidates should be recorded for purposes of comparison.

It should be the policy to employ individuals, as far as practicable, on work suited to their mental and physical fitness. In doing so, consideration will require to be given to general ability, health, temperament, age and service.

Advices of temporary alterations of grades and rates (Fig. 134) should be sent each week to the personnel department in order that appropriate records may be kept, and the works accountant advised in good time, particularly if working under a system of payment by results, to enable him to apportion wages correctly. Permanent alterations should be authorized by the personnel department only.

Job Specifications

There is much to be said in favour of drawing up job specifications, particularly for what may be regarded as

Name	Date of Birth	Present Age	Date Employed	Present Designation	Works Experience	Where Educated	Technical Attainments	Personality	Appearance	Recommendations

Fig. 133. Statement for Comparison of Candidates

TEMPORARY ALTERATIONS OF GRADES AND RATES

Shop No 4

Week ending *27th January* 1940

Clock No	Name	Group No	Period (inclusive) From	Period (inclusive) To	Total Hours	Grade Usual	Grade Temporary	Rate Usual	Rate Tempy	Reason for Alteration
1125	*R Errington*	5	*Monday*	*Wednesday*	*23½*	*Machinist Grade 2*	*Machinist Grade 3*	*44 –*	*42*	***Pressure of work***

Signed

Approved

Fig 134 Shop Advice of Temporary Alterations of Grades and Rates

key grades. The following is a typical example—

Tool Hardener
Heat-treating Section of Tool Shop

Summary of Duties. Hardens tools, jigs and fixtures, and works under general supervision of tool shop foreman.

Work Performed. (1) Conforms to treating process stipulated by Works Metallurgist, depending upon size, shape, use, and material of object. (2) Case-hardening: (*a*) Cyanide treatment: places articles in holders and lowers them into molten cyanide bath; removes articles and quenches them in oil or water, according to instruction. (*b*) Pack treatment: packs, covers with carbon-bearing material, such as charcoal, and seals article in iron box; places article in furnace; allows article to remain in furnace at required temperature for specific time; removes article and quenches it in oil. (3) Plain hardening: Places article in furnace; notes temperature of furnace by means of pyrometer; removes article from furnace and quenches it in oil or water, according to standard instructions.

Furnaces. These consist of the following types: (*a*) Electric, (*b*) Gas, (*c*) Oil, and (*d*) Coal.

Furnaces vary widely in details but all of them have certain essential features. A heating element; space for an article to be heated. Heating and quenching baths. Tanks, with or without heating element, which contain cyanide and brine or oil.

Tools. Tongs, pokers, hooks, and other devices used in handling parts.

Material. Various tools, jigs, and fixtures; cyanide, lead, water, oil; lampblack, charcoal, ground bone.

General Qualifications for Employment. Age: Between 25 and 40 years. Education: Ability to speak, read, and write English. Experience: Preferably two years on similar job, and not less than two years as tool hardener's assistant. Physical: Special sensory acuteness; sight, to discriminate colour in determining temperatures. Special knowledge: A thorough understanding of the effect of heating, cooling, and quenching of metals.

Working Conditions. Surroundings. Inside: Heat, acids, fumes. Hazards: Burns to arms or hands from furnace or heated stock; poisoning due to cyanide getting into open cuts or abrasions; asphyxiation from cyanide fumes.

Promotion to be made from a tool hardener's assistant.

It is important that all grades should be educated with possible promotion in view. Active encouragement should be given for classes to be taken in appropriate subjects, or encouragement given in other ways for employees to improve their knowledge. Trade apprentices should always be given a certificate of apprenticeship (Fig. 135) on completion of their apprenticeship.

Staff Records and Statistics

Service Record. Considered as a whole the most important staff record of all is the up-to-date record which must be kept containing all relevant information of each individual in the concern. From every point of view a card record seems to possess infinite advantages over any other arrangement. A convenient size for such a card is 8 in. by 6 in., the proposed arrangement being depicted in the example given in Fig. 136. It is recommended that these cards be filed in alphabetical order in cabinets.

Details of examination successes or distinctions of a public nature which may have a bearing on future promotions should always be recorded. Similarly, if at any time a logical complaint is registered against an employee and a reprimand decided upon, the date and nature of the offence and the nature of the reprimand should be inserted on the record card. If this is not done there is nothing on record to support what may only be a biased

(NAME OF FIRM)

Date

CERTIFICATE OF TRADE APPRENTICESHIP

I hereby certify that

born on the has served an

Apprenticeship to

in the Works of this Company as follows—

Date commenced Apprenticeship

Date completed Apprenticeship

During this period he obtained experience in the following sections—

During his Apprenticeship he attended evening classes under the local Education Authority, and obtained the following certificates—

Works Manager.

FIG. 135. CERTIFICATE OF APPRENTICESHIP

STAFF RECORD

Surname *WAINWRIGHT* Christian Names *NORMAN*
Date of Birth *1/3/14* Birth Cert Seen *R. H. L.* *13/4/29*
Date Employed *16/4/29* Medical Examination } Class *Grade 1*
Special Qualifications Ref to Papers *A 570*

Date			Grade	Department	Particulars of Promotions, Reductions, Punishments, Gratuities and Injuries	Rate
16	*4*	*29*	*Apprentice*	*Machine Shop*		*10/*
1	*3*	*30*			*Advanced*	*12/*
1	*3*	*31*				*15/*
1	*2*	*32*		*Millwright's Shop*	*Transferred*	
1	*3*	*32*			*Advanced*	*18*
7	*11*	*32*		*Machine Shop*	*Transferred*	
1	*3*	*33*			*Advanced*	*21*
25	*6*	*33*		*Erecting Shop*	*Transferred*	
1	*3*	*34*			*Advanced*	*25*
1	*5*	*34*			*Obtained National Certificate*	
20	*8*	*34*			*L Forearm cut Reference C/24, Compensation £7 10s 6d*	
1	*3*	*35*	*Erector*		*Apprenticeship completed Promoted and advanced Ability very good and very attentive to duties*	*50*
11	*2*	*39*	*Chargeman*	*Erecting Shop*	*Promoted and advanced*	*55*

FIG. 136 SERVICE RECORD CARD

supervisor's or foreman's report on a current charge.

Address Book. The address of the employee must be kept in the office or shop to which he is attached and should be recorded in a foolscap book.

Factory Personnel. A most useful works record is a staff chart drawn up as shown in Fig. 137. It will be seen that every shop grade employed in the factory is catered for, the horizontal columns giving the number in any one grade, whilst the vertical columns give the total number of all grades in each department. This chart should be brought up to date at least once a year.

Age Grouping of Apprentices. A chart which gives the age grouping of apprentices and the total number in each shop, in relation to the number of craftsmen and all adult grades (Fig. 138), is another record worth while keeping, as it shows almost at a glance whether there is any "bunching up" of apprentices of a certain age and also enables one to make comparisons in ratios between different departments. If any "bunching up" does occur, it is proof that the apprentices have not been started at regular intervals as they should have been, regardless of whether or not a craftsman has retired. This problem can be a serious one, but it will not arise if the Larkin system of workshop training, which forms the subject of Chapter XII, is adopted.

Rostered Shifts. A chart of an entirely different type from those already explained is the "duty chart." It should be freely used where rostered shifts are in operation, thus ensuring that groups of men are working to the best advantage. In the particular case illustrated, Fig. 139, it will be seen that between the hours of 10 p.m. and 12 midnight there are six watchmen on duty, whereas five would meet the case, and in the absence of a satisfactory explanation of this some readjustment should be made.

Factories Act

A factory is deemed to be any premises in which, or within the precincts of which, persons are employed on manual labour in any process for any of the following purposes, viz. (*a*) the making of any article or part of an article; (*b*) the altering, repairing, ornamenting, finishing, cleaning, or washing, or the breaking up or demolition of any article; or (*c*) the adapting for sale of any article; such premises being used for work which is carried on by way of trade or for purposes of gain, and to which the employer of the persons therein has the right of access, or over which he has control.

Any private line or siding used in connection with a factory is considered to be part of the factory, but if used by more than one factory belonging to different occupiers, the line is taken to be a separate factory. Premises are not excluded from the definition of a factory by reason only that they are open-air premises.

All factories come within the jurisdiction of the Factories Act, which Act is enforced by factory inspectors, each of whom covers a defined area. In years gone by the factory inspector was often looked upon as a nuisance—to-day in all well-organized factories

CHART SHOWING NUMBER AND GRADES OF WAGES STAFF

Date

Grade		Brass Foundry	Coppersmiths Shop	Erecting Shop	Fitting Shop	Forge	Iron Foundry	Machine Shop	Millwrights Shop	Paint Shop	Pattern Shop	Steel Foundry	Tinsmiths Shop	Welding Shop	Yards	Miscellaneous	Total
Apprentices Trade		6	4	4[illegible]	[illegible]4	4	[illegible]	[illegible]2	[illegible]	2	[illegible]	10	3	2	—	1	217
Assistants Mates and Helpers																	
Attendants		1															
Boys (other than Apprentices)		2															
Bricklayers	*																
Carriers (Metal)		[illegible]															
Case hardeners		—															
Coppersmiths	*																
Coremakers	*	3															
Cupolamen																	
Die Sinkers	*	—															
Dressers Metal (Fettlers)		3															
Erectors	*																
Fitters	*																
Flangers																	
Forge Hammermen																	
Forging Machinemen																	
Furnacemen		—															
Gatemen																	
Grinders		—															
Grinders and Mixers (Paint)																	
Joiners	*	—															
Labourers		4															
Metal Machinists		2															
Metallers White		[illegible]															
Millwrights	*																
Moulders	*	[illegible]															
Moulders Machine		10															
Motor Drivers		—															
Packers		—															
Painters	*																
Pattern makers	*																
Plumbers	*	—															
Porters Office																	
Pressmen																	
Sandmixers		1															
Sawsharpeners and Setters																	
Scrap Shearers																	
Smiths	*																
Stampers Drop Hammer																	
Storesmen		1															
Tinsmiths	*																
Turners	*																
Watchmen																	
Welders	*																
Wood Machinists																	
TOTAL		[illegible]4															

* Denotes Skilled Grades

FIG 137 ANALYSIS OF FACTORY PERSONNEL

Note The horizontal columns will give the number of staff in any one grade and the vertical columns will give the total number of all grades in each shop

AGE GROUPING OF TRADE APPRENTICES
AND
COMPARISON OF NUMBERS WITH ADULT GRADES

Date 1st *January,* 1940

AGE GROUP	LOCATION														
Years	Brass Foundry	Coppersmiths Shop	Electric Shop	Erecting Shop	Fitting Shop	Forge	Iron Foundry	Machine Shop	Millwrights Shop	Paint Shop	Pattern Shop	Tinsmiths Shop	Tool Shop	Welding Shop	Aggregate for Works
14–15	1	—	—	—	9	—	1	12	—	—	—	1	—	—	24
15–16	1	3	1		8	1	2	8	1	—	1	2	—	—	28
16–17	1	2	1		11	—	1	15	2	1	—	1	3	—	38
17–18	2	1	1	8	12	1	—	14	1	—	2	1	2	—	45
18–19	1	1		10	10	—	1	11	2	—	—	1	1	—	38
19–20	2	1	1	12	6	1	1	16	1	1	1	—	2	2	47
20–21	—	2	—	15	12	1	—	16	1	—	1	2	4	1	55
TOTAL	8	10	4	45	68	4	6	92	8	2	5	8	12	3	275
No. of Craftsmen	14	18	16	85	140	24	21	219	30	7	22	20	55	15	686
No. of all Grades over 21 years	42	25	48	132	235	92	106	455	72	22	29	26	78	21	1383
% of Apprentices to Craftsmen	57.1	55.6	25.0	52.9	48.6	16.7	28.6	42.0	26.7	28.6	22.7	40.0	21.8	20.0	40.1
% of Apprentices to all Grades over 21 years	19.0	40.0	8.3	34.1	28.9	4.3	5.7	20.2	11.1	9.1	17.2	30.8	15.4	14.3	19.9
No. of Craftsmen to each Apprentice	1.8	1.8	4.0	1.9	2.0	6.0	3.5	2.4	3.8	3.5	4.4	2.5	4.6	5.0	2.5
No. of all Grades over 21 years to each Apprentice	5.3	2.5	12.0	2.9	3.5	23.0	17.7	4.9	9.0	11.0	5.8	3.3	6.5	7.0	5.0

FIG. 138. AGE GROUPING OF APPRENTICES

he is welcomed as a friend and a consultant. Ignorance of the Factories Act cannot be accepted as an excuse for non-compliance with it. An instance of inefficient staff work came to the notice of the author a short while ago when fines totalling £25 were imposed on a firm of tape weavers and finishers, against whom were preferred nineteen summonses for offences under the Factories Act. The firm was fined £2 for failing to have a machine-gearing fenced securely; £1 for failing to keep a proper register of young persons employed; 10s. in each of four cases of employing a young person for more than seven days without a doctor's certificate of fitness; £2 in each of seven cases of employing women persons on night duty for more than the permitted period; £1 in each of three cases of employing women and young persons for more than the permitted period during the day; £1 in each of two cases of employing women on Sunday; and £1 for employing a young person on Sunday. The firm was also ordered to pay £1 costs.

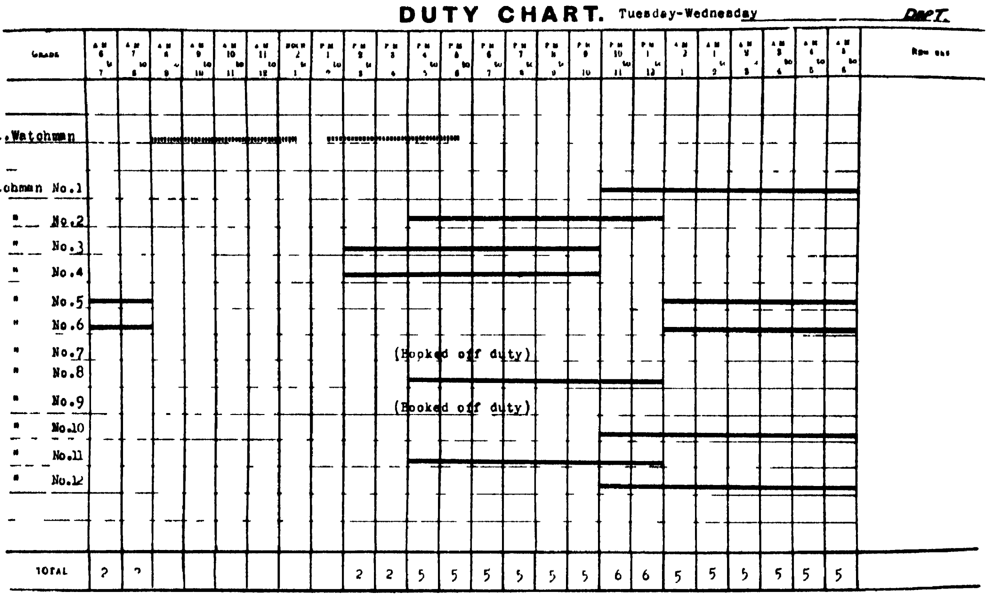


FIG. 139 ROSTERED DUTY CHART

Works and Shops Committees

Absolute honesty in negotiations between employers and employed clears away suspicion and promotes trust. Only in this atmosphere can a permanent settlement, acceptable to all parties, be found. Accordingly, a wise administration will openly favour the setting up of works and shops committees, and give official recognition to balloting for employees' representatives. The object of such a scheme will be to afford full facilities for the settlement of all questions relating to the rates of pay, hours of duty, and general conditions of employment other than matters of

management and discipline. The shop committee should deal with many of the minor difficulties incidental to their own shop and settle them without reference to the higher authority. The works committee should be appointed from the various shop committees. a fair representation aggregating 20 per cent of the latter. This committee will only meet on matters which affect the well-being of the whole concern. The works manager should preside and there should be one or two of his principal assistants present, as well as a senior representative from the personnel department. Minutes should be drawn up of all formal meetings and these should be circulated to those concerned. Typical minutes will read as follows—

MINUTES OF WORKS COMMITTEE HELD IN THE CONFERENCE ROOM ON TUESDAY, 25TH JULY, 1939

Present:

For the Firm:	For the Employees:

The Minutes of the meeting held on 11th February were read.

322. *Safety in Factories— Prevention of Eye Accidents.*

The Chairman informed the Employees' Side that it was the Firm's intention to put forward a lighter type of goggle for use in the Works and samples of these were handed round for inspection. The Committee were informed that this type of goggle was approved by the Home Office, and the samples would be put in the Works for trial. He asked the Committee to do everything possible to ensure that men wore the goggles whilst at work, and so minimize the risk of eye accidents.

323. *Grading of Drop Stampers, Forge.* (*Referred from the Shop Committee of the Forge.*)

The Employees' Side stated this matter had been referred to them from the Shop Committee of the Forge. They were in agreement with the Shop Committee's contention that the time for advancement in the grade should count from the date the man first commenced working in that grade, irrespective of whether in the first place such work was temporary or not; also that any temporary time worked in such grade should count towards the period for advancement, if and when subsequently appointed to such grade.

For the Firm's Side, the Chairman stated he would give the application consideration, and communicate a decision as early as possible.

324. *Payment of Overtime on Shift Working.* (*Referred from the Shop Committee of the Assembly Shop.*)

The Employees' Side stated they were not satisfied with the decision given in this case. They contended that as the normal working week finished at noon on Saturdays, any time worked by men after that time should be paid for at overtime rates. They considered that men working the 6 a.m. 2 p.m. shift were working such shift only for the Firm's convenience and that for the calculation of overtime each day stood on its own, and therefore the claim to overtime rates for shift workers on the 6 a.m. 2 p.m. shift after noon on Saturdays was correct and should be accepted by the Firm.

For the Firm it was pointed out that the payment of overtime in this case had been correctly made. The Employees' Side asked for their failure to agree in the ruling to be recorded.

325. *National Scheme for Physical Training and Recreation.*

The Firm's Side made reference to the renewed campaign of the Government which had for its objects the encouragement of all forms of physical training. It was the desire of the Firm to assist generally the National Movement, and the officials would do everything possible to foster any desire on the part of the staff for recreational facilities. Similarly it was desirable that the Employees' Side of this Committee should encourage the movement, and they were asked to give their co-operation.

The Employees' Side said they would do all they could to help the Movement.

Minutes Agreed:

For the Firm:	For the Employees:
(Signed) W. WOOD.	(Signed) E. SIMKIN.

Notice Boards

Works' and shop notice boards, preferably framed in glass, should always be controlled by one individual, thus ensuring that all notices and posters are given identical prominence and are removed as soon as they have become inoperative, or, alternatively, after a reasonable time has elapsed.

Industrial Psychology

Psychology plays a big part in industrial life, and yet it is only of late years that attention has been paid to it. The National Institute of Industrial Psychology has made tremendous strides and has done much good work, though there is still plenty of scope. One of the secrets of good management lies in giving proper attention and consideration to the staff. What may appear a matter of small moment to the works manager may appear as a mountain to the individual employee.

There are at least two sound reasons why the psychological aspect should be developed—

(1) The best worker has a limited amount of energy, and if this energy can be conserved he will be better able to put more into the actual manipulation of the job and give better results.

(2) If the employee can see that genuine interest is being taken in the conditions under which he works, the psychological effect on him will be all in favour of his giving the best service within his power.

If, for instance, portable pneumatic tools are used, these should be provided with balanced suspensions, thus relieving the operator of the weight of the machine. Similarly, sunken concrete pits into which a job can be lowered should be provided wherever practicable. These allow a man to work at ground level instead of from staging or trestles, both of which latter necessitate tools and equipment being lifted up much higher, and so increase the amount of fatigue.

Industrial psychology is a factor worthy of the fullest consideration, particularly by the supervisory staff, as they have the greatest opportunity of using their knowledge to the best advantage of the manual worker.

Staff Amenities

These include the provision of a works canteen — preferably where meals and light refreshments can be supplied at a nominal cost; a central ambulance station and/or an adequate number of ambulance boxes; cloakroom facilities and lavatory accommodation; washing facilities in the shops—preferably hot water sprays and troughs, and not wash basins; hygienic drinking fountains; a conveniently situated car and cycle park; and special protective clothing and eye protectors. Any or all of these are matters which may rightly be raised at meetings of works and shop committees. They are closely allied to welfare work, yet there is a distinction.

Welfare Work

The largest firms will have one or more officials wholly engaged in welfare development work; smaller firms will be well advised to depute a suitable member of the staff to spend a portion of his time in a similar way. Hospital schemes, sick funds, and

charity appeals require adequate attention. Athletics, swimming, tennis, hockey, netball, football, cricket, bowls, and other pastimes are all to be encouraged. For indoors, facilities for an engineering society, literary society, dramatic society, library, reading room, and games room will assist in bringing together all grades of employees and help to maintain *esprit de corps*. Outstanding successes for the few are not nearly so satisfactory as when a large percentage of employees take part in pastimes or recreation. A magazine should be issued, preferably monthly, but an issue bi-annually or even annually is well worth while, and will do much to foster a good spirit.

A small welfare committee representative of the management and the employees will be able to co-ordinate in a most effective manner.

Outside Assistance

In England the Industrial Welfare Society, membership of which is open to firms and individuals alike, provides considerable practical assistance for its members. Briefly classified this assistance can be said to cover the following eight sections--

1. Publications. Members receive bulletins and memoranda on special aspects of welfare work.

2. Health. An advisory medical committee meets regularly to discuss developments in industrial medical research and medical problems arising in industry.

3. Accident Prevention. Assistance is given in the establishment of safety committees, compilation of accident statistics, guarding of machinery, and education in safe working conditions. In co-operation with the National "Safety First" Association, accident-prevention posters are issued and an information service is maintained.

4. Legal. Advice is given on benevolent, pension, and superannuation funds, group insurance, savings schemes, rating, taxation, licences, statutory regulations, club rules, and other problems.

5. Recreation. Information is available on all aspects of works clubs. Assistance is given in drawing up the rules and constitution of indoor and sports clubs, and in their finance and administration. Schemes are submitted for the layout of sports grounds and the establishment of camps and other holiday centres.

6. Canteens. Questions of administration and management are dealt with and advice given on the establishment of new canteens.

7. Employment. Information is available on the organization of an employment department, personnel records, education, training, and promotion schemes, incentives and labour turnover problems.

8. Appointments. A panel of persons qualified to hold positions as employment managers, welfare supervisors, works doctors, nurses, canteen managers, and others, is maintained. The Society's experience is of value in assisting firms to make satisfactory appointments, and in advising candidates on training.

CHAPTER XI

INDUSTRIAL ACCIDENTS—AND THEIR PREVENTION

LOSSES due to industrial accidents and industrial diseases arise by payment of compensation for partial or total incapacity, and by reduction in output due to the absence of the employee. The payment of compensation is perhaps the more obvious, but if anyone doubts the latter he has only to study the Annual Report of the Chief Inspector of Factories and Workshops in order to realize its significance.

It is gratifying to record that there is a genuine and ever-increasing desire on the part of employers to improve the conditions of their factories and reduce the number of accidents as well as industrial diseases. The employer who is worthy of the name will always recognize that every employee who serves him is a human being and is entitled to the highest skill and care that modern science can offer.

The factory inspectors, all of whom are appointed by the Home Office, and of whom there is one in every district, can give much useful advice. There is nothing to lose and much to learn by their co-operation. These experienced officers are entitled to visit the factory "at all reasonable times," and their combined efforts have brought to light many excellent safety devices and precautionary measures.

Nor will it be out of place here to mention the very real and practical help that can be derived from a visit to the Home Office Industrial Museum in London. It will be time well and truly spent.

Safety Precautions

The old adage "prevention is better than cure" should be applied to the workshop on every possible occasion, and some applications of a general character may be tabulated.

(1) The gangway should always be kept clear. White lines two to three inches wide are recommended for this purpose.

(2) Attention should be paid to the periodic disinfection of the oils used as coolants during cutting. After a time oil tends to become infected by bacteria, which may cause infection of the skin of people's hands when they are continually exposed to oil, although there may be no obvious wound in the skin. Chemicals are available, small quantities of which can be added to the oil, rendering it sterile and removing this source of danger.

(3) In dry grinding operations it is of the utmost importance to use the best possible means for collecting dust so as to keep the atmosphere as free as possible from the minute particles of abrasive, which are not only injurious to health but are a source of considerable wear and tear to machines.

(4) Revolving shafts and spindles on machine tools which cannot be covered should always be regarded as dangerous. Even a perfectly smooth

revolving shaft has a tendency to pick up anything soft, such as the sleeve of a coat, and if the shaft is castellated or splined the danger is very much increased.

(5) Drilling machines are never free from risk of accident. Loose sleeves are a constant danger and tight sleeved overalls or sleeves turned up above the elbow should be insisted upon.

(6) Every woman working in a factory should have her hair completely covered by a neat cap. A woman's scalp may be torn off completely through her loose hair becoming entangled in a machine.

(7) It is very important that work and jigs should be properly secured during drilling operations, otherwise they may start to revolve and serious damage occur.

(8) Spiral cuttings can inflict very dangerous wounds. Labourers handling cuttings of this kind should be provided with leather gloves. Similarly, milling machine operators should always have brushes for removing the swarf from work and from jigs. The needle-like chips produced by milling inflict troublesome skin injuries. Sharp edges left by machining operations frequently cause serious cuts.

(9) Many accidents occur through the unexpected release of muscular tension. An ill-fitting spanner slips off its nut, the sudden release of tension brings the hand or arm into contact with some stationary or moving part of the machine, and injury is inevitable. The condition of spanners requires constant attention as the jaws become worn and dangerous in a comparatively short time.

(10) By the adoption of effective leather spats in the foundry, injuries due to hot metal will almost entirely disappear.

(11) Piling and stacking of articles, if badly done, is a source of injury. In pulling one job off a pile it is very easy to pull another on to one's foot.

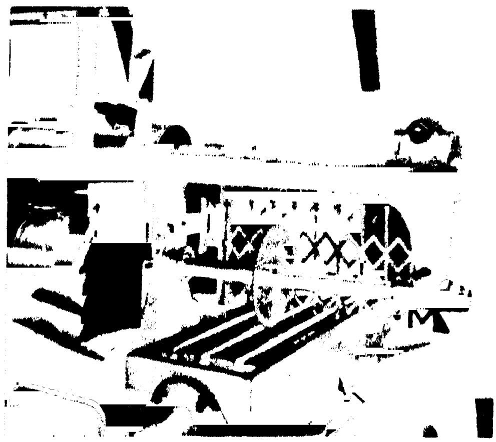


FIG. 140. MACHINE GUARD, EXPANDING TRELLIS TYPE

(12) Ladders need continual inspection and should never be used if they have broken or weakened rungs. The foot of every ladder should be fitted with spikes or non-slipping attachments.

(13) Nobody should be allowed to touch belting or lubricate shafting unless it is completely stationary. Many accidents of a most serious nature have occurred from this cause.

(14) An operator should not only be able to stop his own machine but he should also know how to stop the machines working on either side of him.

(15) When machine guards can be introduced the types shown in Figs. 140, 141, and 142 can usually be

recommended. These illustrations depict corrugated lattice and trellis machinery guards, both of which types afford excellent protection. They are light and rigid, and give clear visibility. Lattice and trellis guards

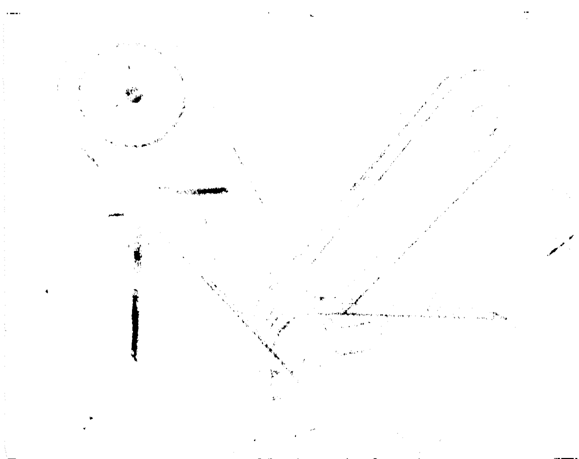


FIG. 141 MACHINE GUARD, LIGHT WIRE TYPE

and partitions can be made in all workable metals and may be lacquered, painted, or galvanized. It should be noted that if a machine is located in a dust-laden atmosphere, moving parts should be completely housed with a sheet metal guard.

Quite apart from the humanitarian point of view, the lack of suitable machine guards can prove to be a costly matter. As an example, a boy of 19 years of age, employed by a firm of gas engineers, was recently awarded damages of £1800 and costs for the loss of four fingers on the right hand. According to the evidence submitted at the Assizes the accident occurred on the second day of the boy's employment with the firm. He was in charge of an embossing press, and in bending down to pick up a plate his right hand was caught under the die and crushed, four fingers subsequently having to be amputated. The judge found there had been negligence by the firm in not providing the machinery with a guard.

(16) The necessity for wearing goggles cannot be over-stressed. The processes involved are as follows—

(*a*) Dry grinding of metals or articles of metal applied by hand to a revolving wheel or disc driven by mechanical power.

(*b*) Turning (external or internal) of non-ferrous metals, or of cast iron, or of articles made of such metals or such iron, where the work is done dry (other than precision turning where the use of goggles or a screen would seriously interfere with the work), or turning by means of hand tools.

(*c*) Welding or cutting of metals by means of an electrical, oxy-acetylene or similar process.

Also the following processes, when carried on by means of hand tools or other portable tools:—

(*d*) Fettling of metal castings involving the removal of metal.

(*e*) Cutting out or cutting off (not including drilling or punching back) of cold rivets or bolts from boilers or other plant or from ships.

(*f*) Chipping or scaling of boilers or ships' plates.

(*g*) Breaking or dressing of stone, concrete or slag.

Safety Precautions Booklet

It is advisable to issue to every employee a booklet in connection with safety precautions. These instructions might include such as the following—

1. *Reporting of Accidents and First Aid Treatment.* In order to secure compensation, an employee must be able to prove that his injury was sustained while following his employment, and arose out of his employment. As soon as practicable you should report the accident to your immediate superior. Injuries which seem trivial when they are received sometimes develop into permanent disability. On meeting with an injury, however small, go at once to an ambulance man or the Ambulance Room for treatment, even if you do not think it really necessary.

2. *Conduct.* Many accidents occur through thoughtlessness. It is in your own interests for you to be alert and not to act in a manner likely to cause injury to yourself and others.

3. *Quarrelling and Idling.* In your own interests you should avoid idling, playing or quarrelling, as such practices frequently lead to accidents. If an accident should result from such practices, the management will take a serious view of the matter.

4. *Permitted Routes.* On all occasions use the permitted routes to and from your place of work.

5. *Pits.* A sprained ankle or wrist, or a broken rib, may easily result from jumping over pits. Always walk round, or use a pit plank.

6. *Dirty Waste.* Do not leave dirty or greasy waste lying about, but place it in the receptacle provided for such material.

7. *Smoking.* A lighted match dropped after lighting a pipe or cigarette may cause a fire. Matches should be extinguished when you have finished with them.

Do not indulge in smoking, in any circumstances, in shops where it is prohibited. The reason for the prohibition is the special risk of fire because of the inflammable nature of the materials used.

8. *Inflammable Stores.* To smoke, strike matches, or use naked lights in or near naphtha, petroleum or other inflammable stores, or near empty vessels which have contained inflammable liquids, is to run the risk of serious injury as well as of destruction to property and material, and is therefore absolutely forbidden.

9. *Tools.* Make sure that the tools you use are in good condition and suitable for the work to be performed. Defective tools, which have been supplied by the firm, can be changed at the Tool Stores.

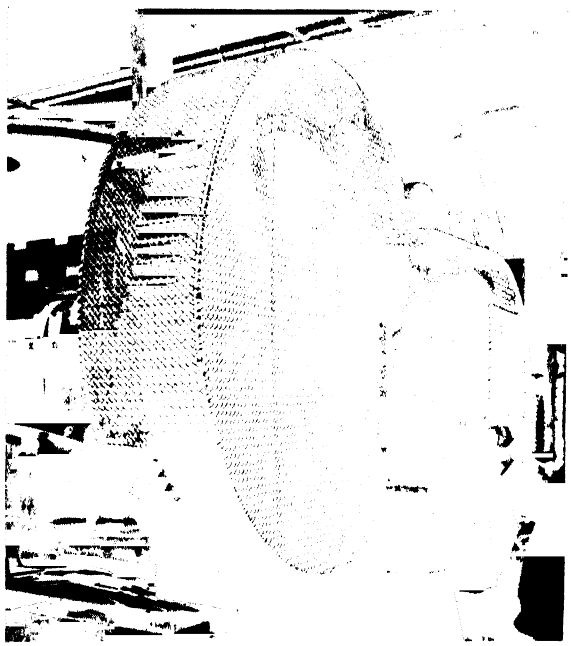


FIG. 142. MACHINE GUARD, HEAVY WIRE TYPE

10. *Striking a File with a Hammer.* Using a broken file in place of a punch is dangerous, as pieces of the file sometimes fly and may cause loss of sight.

11. *Striking Hardened Steel.* A soft hammer should be used as otherwise chips may fly off resulting in loss of sight.

12. *Chipping.* When chipping any kind of metal, care should be taken to prevent the chippings from flying in the direction of other persons.

13. *Guiding Saws.* In starting a two-handed cross-cut saw, a block of wood is better than a hand for guiding.

14. *Interference with Machinery.* Unless

an emergency or accident warrants it, no one, other than the person whose ordinary employment it is, may interfere with any tools or machinery, or start or stop any machine, unless specially authorized to do so by the foreman.

15. *Defects in Machinery or Workshops.* Employees should call the immediate attention of their foreman to any defect in machinery or workshops.

16. *Guards on Machinery.* Guards and other appliances are provided for the specific purpose of avoiding accidents. Fencing guards should not be removed or kept off while the machinery is in motion. Fencing that may have been removed whilst a machine is stationary should be replaced before it is set in motion.

17. *Cleaning Machinery.* For your own safety, do not attempt to oil or clean moving parts of any engine, crane, or other machine, while they are in motion.

18. *Moving Belts from One Pulley to Another.* Do not use your hand to move belts from one pulley to another. Use a pole or stick.

19. *Removing Borings, etc.* Never try to remove borings, drillings, turnings, etc., by hand, or the hand may be cut or trapped. Always use a brush or stick.

20. *Steam, Power, and Drop Hammers.* If you work in connection with steam, power, or drop hammers, do not put your hands between the hammer heads and blocks; use tongs, or else satisfy yourself that the hammer heads are properly secured or lowered on to the stop blocks provided. Steam hammer drivers must not lower the hammers before receiving the signal from the forgemen, and they must then satisfy themselves that everything is clear.

21. *Clothing.* Many a serious accident has resulted from unsuitable clothing being worn by men operating lathes and other machines. Jackets should be made to button tightly, cuffs should be provided with buttons or other means of fastening tightly round the wrist, and jackets and cuffs should be kept buttoned.

22. *Eye Protectors.* Eyesight is precious. Do all that you can to preserve it. Use goggles on all occasions where there is the slightest risk of injury to the eye. Even if a little inconvenient, it is worth it. If the glasses fog, this can be remedied by slightly moistening the finger and applying a film of soap to the glass, afterwards wiping off with a clean dry cloth.

23. *Respirators.* It is better to keep out of your system the dust that arises when grinding, buffing, and scrubbing old metal work, or doing other dusty jobs. Use respirators; keep them clean; change the wool pads at least once a day.

24. *Grinding Wheels.* When grinding wheels are chipped, damaged or untrue, advise the foreman and have the wheel turned up. Rests in front of wheels should always be kept close to the wheels.

25. *Hot Metal or Slag.* It is dangerous to run hot metal or slag into a wet mould or ladle. See also that metals are dry before being placed into a hot melting pot.

26. *Electrical Switchgear.* Electrical gear should be treated with extreme caution. Do not interfere with any electrical apparatus unless you are authorized to do so. No one should operate any switch to which is attached a red "Danger" board. Before handling the switches of electrically driven machines, operators should see that their hands are perfectly dry. When any work has to be done on or in such proximity to the cables or switchgear of electrical machinery that there is a danger of accidental contact being made, the permission of the shop foreman should be obtained to have the current cut off the section, and a "Danger" board should be fixed on the switch before such work is commenced.

27. *Fires on Electric Switchboards.* Do not use a hose to extinguish a fire on an electric switchboard.

28. *Putting in Electric Globes.* Never put electric globes in the holders while the switch is on. Lamps sometimes burst and damaged hands result.

29. *Lifting Articles or Material.* When lifting heavy articles or material, especially from the ground, keep the feet close together, slightly bend the knees, and assist in the lifting by straightening the legs. Many ruptures are caused through disregarding this rule.

30. *Ladders.* Make sure that the ladder you are going to use is suitable. Whether or not a spiked ladder should be used must be determined by the nature of the surface on which the ladder is required to stand. Whenever practicable, and particularly in cases of going up to any considerable height, the ladder should be held at the foot and if possible secured at the top. In your own interests you should draw immediate attention to any apparent defect.

Safety First Notices

It is desirable that large printed notices should be posted wherever they may be considered to serve a useful purpose. As a case in point the following would be suitable for posting in a grinding shop.

SAFETY FIRST

(1) The work rest should be adjusted close to the face of the wheel to prevent work catching between wheel and rest.

(2) The work rest should be adjusted as the wheel is reduced in diameter.

(3) Keep wheels perfectly true, either with a dressing tool or diamond. Never use a chipping hammer.

(4) When a new wheel is mounted, it should be run free at its operating speed for a minute to make certain that the wheel has not been damaged during mounting.

(5) Work should never be forced against a cold wheel, as the sudden heating may cause the wheel to break.

(6) Wheels which are used for wet grinding, should not be allowed to stand partly immersed in water, as this will throw the wheel seriously out of balance.

(7) It is often dangerous to grind on the sides of a flat, straight wheel, particularly when the sides of the wheel are considerably worn.

(8) Above all, make certain that your goggles are in good order and properly adjusted.

Juvenile Employees

An examination of Government reports reveals that the accident risk of a young person (anyone under 18 years of age) is very high in the first few months of service. The incidence of the curve, Fig. 143, shows what takes place. Accordingly, upon entering the service it is strongly recommended that each boy or girl should be

(1) Handed a copy of the safety precautions booklet and instructed to read it carefully in order to familiarize himself with its contents.

(2) Taken round the shop in which he is to be employed and instructed as to the principal dangers, such as approach to transmission machinery, the necessity for keeping guards in position, etc.

(3) Warned against "pranks."

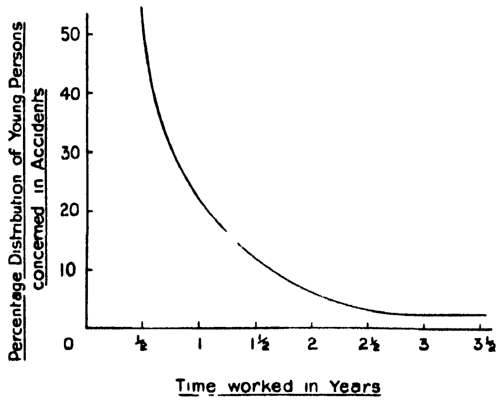


FIG 143. ACCIDENTS TO JUVENILE EMPLOYEES

(4) Placed under the direct supervision of a competent person for the initial period of his employment.

If the new entrant is to be employed on a machine, he must also be

(5) Warned of the dangers of the machine.

(6) Properly instructed in the operations to be carried out.

(7) Placed under the direct supervision of someone who is familiar with the machine and its dangers.

Ambulance Room

A fully equipped first aid room combined with rest room will almost certainly prove a good investment. In large factories it should be a rule that only the sister-in-charge in the ambulance room should say whether or not a patient should be removed to hospital, this ensuring that all cases are

REPORT OF ACCIDENT

Department. Ref. No.

Full Name of Injured Person

Grade Pay No.

SECTION A. DETAILS OF ACCIDENT

1. Date 19 2. Time M.

3. Nature and Degree of Injury.
   State (*a*) whether right or left leg, arm, eye, etc.
   (*b*) whether slight, severe, or fatal

4. Place (to be particularized)

5. *Give description of accident, indicating to which of the following causes the accident was due*—
   (*a*) Misadventure. (*b*) Want of ordinary caution on the part of injured person. (*c*) Misconduct of injured person. (*d*) Breach of rules or regulations by injured person. (*e*) Want of ordinary caution on the part of other persons. (*f*) Misconduct of other persons. (*g*) Breach of rules or regulations by other persons. (*h*) Failure of the injured person to wear goggles provided. (*j*) Clothing of the injured person being caught in machinery, shafting, etc. (*k*) Defective apparatus; defect to be particularized. (*l*) Other specific cause (to be particularized).
   (Description must be adequate—If this space is insufficient, attach separate sheet.)

6. (*a*) Was accident witnessed? (*b*) If so, give names, occupations, and addresses of witnesses
   (*c*) Give date statements of witnesses obtained
   (*d*) Are statements attached or to follow?

7. (*a*) Did accident occur in connection with vehicle or machine? If so, state which
   (*b*) Was vehicle or machine in motion at time of accident?
   (*c*) Give identification of vehicle or machine

8. Are you satisfied (*a*) that the accident, as alleged, did occur?
   (*b*) that the injury is consistent with the accident reported?
   (*c*) that the accident occurred whilst the injured person was on duty?

9. *What precautions, if any, have been taken, or are recommended for adoption, to prevent recurrence of such an accident?*
   (If this space is insufficient, attach separate sheet, and if unable to answer question fully at time of reporting accident, a special report is to be sent later)

Report to Signature of Foreman

.. . .. Date 19

NOTE. *The information on this side of the form to be supplied by the Foreman.*

(For instructions see other side.)

FIG. 144. ACCIDENT REPORT (*front*)

NOTE. *The following information to be supplied by the Works Manager.*

SECTION B. PARTICULARS OF INJURED PERSON

10. Age years. Length of service years.
11. If injured person employed less than one month on grade of work on which engaged at time of accident give date on which first so employed
12. (Fatal accidents only) Married or Single Children Other dependants (if any)
13. Private address

Did injured man go home or to hospital?

By what means?

14. Present address, if not at home, e.g. hospital
15. Is injured person a member of an Accident Fund or Benefit Society certified under Section 31 of the Workmen's Compensation Act, 1925?
If so, give (*a*) Name of Fund or Society
(*b*) Date of declaration on Fund or Society
16. Is injured person insured under National Health Insurance Act?

SECTION C. HOURS OF DUTY OF INJURED PERSON

17. Regular Working Hours.
From M. To M.
Booked intervals for meals or rest.
From M. To M.
19. When did injured person cease work in consequence of accident? Time M.
Date 19
18. Time commenced duty on date of accident M. Length of time on duty up to time of accident hrs. mins.
20. Was injured person off duty for one whole day owing to accident?
21. (*a*) When was accident reported by injured person? 19 (Time) M.
(*b*) To whom was accident reported?
(*c*) If not reported at time of occurrence, state why
also how and when did the Company become aware of the injury

SECTION D. MEDICAL ATTENDANCE AND FIRST AID

22. Name and address of Doctor attending injured person
Is this Doctor his Panel Doctor?
23. (*a*) Was a doctor called in at time of accident? (*b*) If so, state name and address
(*c*) By whom was he called in?
24. Was first aid rendered? If so, state name or names and grade

Signed Works Manager.

Date 19

INSTRUCTIONS

1. In all cases of accidents to employees, whether it involves absence from duty or not, a report on this form is to be prepared by the responsible person in charge, and sent immediately to the Works Manager.
2. If two or more persons are injured as a result of one accident, separate forms should be used for reporting each case.
3. When injuries have been caused by neglect or misconduct of other persons, full particulars to be reported of how, and by whom, injury was caused, and particularly in what respect person causing injury was to blame. Names and addresses of persons who witnessed, and can prove, the negligence or misconduct to be reported.
4. Wherever possible, all witnesses of an accident should be requested to sign a statement giving full details of the occurrence.

FIG. 144 (*contd.*). ACCIDENT REPORT (*reverse side*)

treated with uniformity. If, as is very desirable, a motor ambulance is kept, it should be a duty of the transport officer to see that it is always ready for immediate use and in good running order, as well as being spotlessly clean.

Accident Report

In order to ensure uniformity in the recording and reporting of accidents it is highly desirable that a standard form should be drawn up, and a copy used on every occasion of an accident which prevents the individual carrying on his normal duties. The type of accident report recommended is shown in Fig. 144. There should be a report book kept by each shop as per Fig. 145, and one by the personnel department as per Fig. 146.

Where the nature of the accident or injury is such that it necessitates the employee being away from duty for a period of three or more days, it becomes a reportable case to the district factory inspector, and a copy of the accident report must be sent to him within seven days of the date of the accident occurring.

Accident Statistics

An analysis of accidents which have occurred in the year, resulting in one complete day or more of absence from work, should be arranged as shown in Fig. 147. There should also be an annual return showing the number of accidents and frequency and severity rates as shown in Fig. 148.

The total amount of compensation payments made during each year should be recorded in the manner shown in Fig. 149.

Workmen's Compensation Acts

An Act which was passed in 1925 and came into operation on the 1st May, 1926, consolidated the law relating to compensation to employees for injuries suffered in the course of their employment.

With certain reservations it applies to any person who has entered into, or works under, a contract of service or apprenticeship with an employer, whether by way of manual labour, clerical work or otherwise, and whether the contract is expressed or implied, is oral or in writing.

Any person employed on other than manual labour whose remuneration exceeds £350 per year, and any person whose employment is of a casual nature other than for the purpose of the employer's trade or business, not being a person employed for the purpose of any game or recreation and engaged or paid through a club, is excepted.

Dependants Entitled to Compensation. The dependants of an employee entitled to claim compensation under the Act *where the injury results in death* are such of the members of the employee's family as were wholly or in part dependent upon the earnings of the workman at the time of his death, or would have been so dependent but for the incapacity due to the accident.

A person shall not be deemed to be a partial dependant of another person unless he was dependent partially on contributions from that other person for the provision of the ordinary necessities of life suitable for persons in his class and position. A posthumous

Full Name Address and Occupation of Injured Workman	Signature of Injured Workman or Other Person making this Entry (If the entry is made by some person acting on behalf of the workman the address and occupation of such person must also be given)	Date when Entry Made	Date of Accident	Room or Place in which Accident Happened	Cause and Nature of Injury
(1)	(2)	(3)	(4)	(5)	(6)
Arthur Dickens Turner Burton Road Derby	*A Dickens*	*21 1 40*	*21 1 40*	*Lathe Section of Machine Shop*	*The tip of a stationary Centre broke off, allowing a bar of steel to fly out of the lathe bruising muscle of the left thigh*

FIG 145 REPORT BOOK USED IN WORKSHOP

Date of Accident	Date of Notice on Form 43 to Inspector	How Caused (e g whether by machinery in motion and by what part of such machinery)	Name of Person Injured	Sex	Age	Usual Employment	Precise Occupation at Time of Accident	Nature of Injury and whether Fatal or Not	Dates on which the Person was Disabled from Earning Full Wages at the Work at which he was Employed
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
21 1 40	*26 1 40*	*The tip of a stationary Centre broke off allowing a bar of steel to fly out of the lathe bruising muscle of the left thigh*	*Arthur Dickens*	*Male*	*23*	*Turner*	*Turner*	*Bruised muscle of left thigh causing slight lameness*	*21 1 40 to 25 1 40*

FIG 146 REPORT BOOK USED BY PERSONNEL DEPARTMENT

ANALYSIS OF ACCIDENTS RESULTING IN ABSENCE FROM DUTY FOR ONE

Class of Accident	PRIMARY CAUSE											
	Mis-adventure (a)		Lack of Ordinary Caution on the Part of Injured Person (b)		Misconduct of Injured Person (c)		Breach of Rules or Regulations by Injured Person (d)		Lack of Ordinary Caution on the Part of Other Persons (e)		Misconduct of Other Persons (f)	
	Y.P.	A.	Y.P.	A	Y.P.	A.	Y.P	A	Y.P	A.	Y.P.	A
1. ACCIDENTS IN CONNECTION WITH POWER-DRIVEN MACHINERY IN MOTION, INCLUDING TRANSMISSION MACHINERY, LIFTING APPLIANCES, CRANES, AND WINCHES.												
(i) Cleaning, oiling or examining	1											
(ii) Adjusting or operating machinery	2	2		4			1	1		2		
(iii) Other accidents												
2. ACCIDENTS DUE TO FALLING OR SLIPPING.												
(i) On floor, in yard, or into pits	1	9			1							
(ii) From ladders, staging, roofs	1	7										
3. ACCIDENTS DUE TO BEING STRUCK BY FALLING OBJECTS												
(i) Objects dropped by workers overhead												
(ii) Objects dropped from cranes, slings		3										
(iii) Objects dropped by injured persons	1	4		6		1		2				
(iv) Other falling objects	3	13										3
4. ACCIDENTS DUE TO STRIKING OR BEING STRUCK BY PROTRUDING OBJECTS.												
5. EYE INJURIES FROM FLYING PARTICLES AND CHIPPINGS.												
(i) From abrasive wheels												
(ii) Whilst chipping, riveting, and caulking, by hand		1										
(iii) Ditto, by power-driven tools												
(iv) From work in machines		1										
(v) Whilst stripping, cleaning or assembling vehicles, locomotives, boilers (other than (ii) and (iii))		1										
(vi) By work of other persons		1										
(vii) Other causes		3										
6. ACCIDENTS IN CONNECTION WITH USE OF TOOLS.												
(i) Hand tools	3	4		3				4				
(ii) Portable power tools		6										
7. ACCIDENTS DUE TO LIFTING ARTICLES.												
(i) Strains, sprains, ruptures		3		5		1		2				
(ii) Cuts, bruises, abrasions	1	5										
8. ACCIDENTS CAUSED BY STRAINS OTHER THAN BY LIFTING ARTICLES.												
9. ACCIDENTS CAUSED BY BURNS OR SCALDS (other than electric shock explosions)	1	5										
10. ACCIDENTS IN CONNECTION WITH MOVING VEHICLES, SHOP TRUCKS, AND BARROWS.												
(i) Hand drawn		5										
(ii) Power driven												
11. ACCIDENTS REQUIRING SPECIAL INVESTIGATION, SUCH AS GASSING, ELECTRIC SHOCK, AND EXPLOSIONS.												
12. OTHER CLASSES OF ACCIDENTS	1	6		2		1		5		3		
Total number of accidents resulting in absence from duty for one complete day or more (all classes of accident, 1 to 12 above)	15	79		20	1·	3	1	14		5		3

Note. Y.P. – Young Persons (i.e. Employees under 18 years of age)

FIG. 147. ANALYSIS

COMPLETE ...

OF ACCIDENT

Br..h of R..s or Reg..ations ... other Persons		Failure of the Injured Person to Wear Goggles (h)		Clothing of the Injured Person being Caught in Machinery, Shafting, etc. (j)		Defective Apparatus (k)		Other Specific Cause (l)		Total Number of Accidents Due to Causes (b) to (l) only			Total Number of Accidents Due to All Causes (a) to (l)		
Y.P.	A.	Y.P.	A.	Y.P.	A.	Y.P.	A.	Y.P.	A.	Y.P.	A	TOTAL	Y.P.	A	TOTAL
													1	—	1
	1				1		1			1	10	11	3	12	15
										1	–	1	2	9	11
													1	7	8
													–	3	3
							1		1		11	11	1	15	16
	1						2		2		11	11	3	24	27
													—	1	1
													—	1	1
														1	1
														1	1
														3	3
							2		1		10	10	3	14	17
														6	6
											8	8		11	11
													1	5	6
			1								1	1	1	6	7
													–	5	5
							2		7		20	20	1	26	27
	5		1		1		8		11	2	71	73	17	150	167

Adults (i.e. Employees 18 years of age and over).

OF ACCIDENTS

child at the time of the father's death is deemed to have been born so far as it is for the benefit of such child.

By the Workmen's Compensation (Supplementary Allowances) Act, 1940, the scale of payments laid down by the Act of 1925 was increased

Meaning of "Employer" in the Acts. Where the services of a workman are temporarily lent or let on hire to another person by the person with whom the workman has entered into a contract of service or apprenticeship, the latter shall, for the purpose of the Acts, be deemed to continue to be the employer of the workman whilst he is working for that other person.

Weekly Payments for Partial Incapacity Compensation. In cases where a workman is partially incapacitated and his pre-accident earnings are thereby reduced, partial incapacity compensation is paid, the amount paid being determined by a somewhat involved mathematical calculation. As will be seen later, the basis of the calculation is the pre-accident earnings

NUMBER OF ACCIDENTS AND "FREQUENCY" AND "SEVERITY" RATES DURING THE YEAR 1940

Details	Accidents		Industrial Diseases	
	Young Persons	Adults	Young Persons	Adults
(A)	(B)	(C)	(D)	(E)
1 Number of accidents causing absence for one full day or more, but less than a week	44	4	—	
2 Number of accidents causing absence for one week or more	92	12	1	2
3 Number of accidents causing known permanent partial disablement		—		
4 Number of accidents causing known permanent total disablement				
5 Number of fatal accidents		1		
6 Total number of accidents (1 to 5 above)	136	17	1	2
7 Number of 10,000 man hours worked in the period	742	70	743	742
8 Number of hours lost during the period by accidents which occurred in the period	20 900¼	1,957¾	199	1,283
9 "FREQUENCY RATE" (i e number of accidents per 10,000 man hours worked during the period)	18	24	001	003
10 "SEVERITY RATE" (i e number of hours lost during the period per 10,000 man hours worked during period)	28 17	27 97	27	1 73

Note Wherever the word Accidents is used it also includes 'Industrial Diseases"

FIG 148 NUMBER OF ACCIDENTS AND FREQUENCY AND SEVERITY RATES

of the workman and the average weekly amount which he is earning or is able to earn in some suitable employment after the accident.

Average Earnings of a Workman. As a basis for fixing a workman's total incapacity compensation rate, his weekly earnings for twelve months prior to the accident are taken and divided by 52, the amount arrived at being determined as his pre-accident earnings.

The divisor of 52 is reduced in certain cases (six days constituting one week) to allow for illness, accidents on duty, special leave without pay, disciplinary suspension, and accidental breakdown of plant or machinery. It is important to note that in the case of works holidays, short time working, absence without leave, and strikes (including time lost as the result of strikes not immediately connected with the workman's employment) such absences do NOT constitute a break in the employment. Accordingly no deduction is made from the divisor in respect of them, the actual earnings being taken and divided by the full 52 weeks. Fig. 150 summarizes the application of the Acts in the case of both total and partial incapacity.

Fatal Accidents. The compensation to be paid for a fatal accident is calculated as follows—If the workman leaves any dependants wholly dependent on his earnings, the lump sum shall be a sum equal to his earnings in the employment of the same employer during the three years preceding the injury, or the sum of £200, whichever is the larger, but not exceeding in any case £300, exclusive

TOTAL AMOUNT OF COMPENSATION PAYMENTS MADE DURING THE YEAR 1940

Classification	Amount of Compensation Paid (A) Current Payments in Respect of Accidents during the Year	(B) Commutations	(C) Payments in Fatal Cases	(D) Total	(E) Total Amount of Wages Paid	(F) Amount of Compensation paid per £100 Wages: On Current Payments (Col. A)	On All Payments (Col. D)
	£	£	£	£	£	s. d.	s. d.
Accidents	643	215	88	946	580,821	2 2¼	3 3¼
Industrial Diseases	6	—	—	6	580,821	0¼	0¼

FIG. 149. COMPENSATION PAYMENTS

RATE OF WEEKLY COMPENSATION PAID FOR TOTAL INCAPACITY

(a) Where average weekly earnings amount to or exceed 50s.

Average Weekly Earnings for 52 Weeks Prior to Date of Accident	Computation of Rate of Compensation	Amount of Compensation	Supplementary Allowance	Total Amount Payable
50s. or over	50 per cent, but not exceeding 30s.	—	5s.	—
E.g.— 54s.	50 per cent	27s.	5s.	32s.

(b) Where average weekly earnings are under 50s.

Typical Average Weekly Earnings	Method of Computation				
	50 per cent of Average Weekly Earnings	Difference between 50 per cent of Average Earnings and 25s. or the Average Earnings (whichever is the less)	50 per cent of Such Difference to be Added to 50 per cent of Average Weekly Earnings	Supplementary Allowance	Total Amount Payable
s. d.	*s. d.*	*s. d.*	*s. d.*	*s. d.*	*s. d.*
45 0	22 6	2 6	1 3	5 0	28 9

EXAMPLE -

	s. d.	
In the case of an employee earning 50s. per week he would receive	30 0	i.e. 25s. weekly compensation plus 5s. supplementary allowance.
With one child he would receive	34 0	i.e. 25s. compensation plus 5s. supplementary allowance and 4s. children's allowance.
With two children he would receive	38 0	i.e. 25s. compensation plus 5s. supplementary allowance and two amounts of 4s. children's allowances.
With three children he would receive	41 0	i.e. 25s. compensation plus 5s. supplementary allowance and a further 3s. children's allowance.
With four children he would receive	43 9	i.e. 25s. compensation plus 5s. supplementary allowance and a further 2s. 9d. in respect of children's allowances.

because the ⅞ths maximum allowance stipulated in the Act of 1940 would then be reached.

RATE OF WEEKLY COMPENSATION PAID FOR PARTIAL INCAPACITY

EXAMPLE

	s. d.	
If an employee was earning 50s. per week before his accident and 40s. per week after returning to work he would receive	6 0	i.e. a partial incapacity payment of 5s. and 1s. supplementary allowance, the partial incapacity payment representing ⅕th of the total incapacity payment, which would be 25s. per week.
With one child he would receive	6 10	the additional 10d. representing ⅕th of 4s. per week.
With two children he would receive	7 8	representing 10d. additional for the second child.
With three children he would receive	8 3	being an addition of 7d. representing ⅕th of 3s. per week.
With four children he would receive	8 9	an addition of 6d. only.

because 8s. 9d. is ⅞ths of the difference between the pre-accident and post-accident earnings, and ⅞ths is the maximum allowance.

FIG. 150. APPLICATION OF THE WORKMEN'S COMPENSATION ACTS

INDIVIDUAL SHOP ANALYSIS OF ACCIDENTS

SHOP

YEAR

	CAUSE OF ACCIDENT											
	Misadventure	Lack of Ordinary Caution by Injured Person	Misconduct of Injured Person	Breach of Regulations by Injured Person	Lack of Caution by Others	Misconduct of Others	Breach of Regulations by Others	Failure to Wear Goggles by Injured Person	Clothing being Caught in Machinery	Defective Apparatus	Other Causes	Total
CLASS OF ACCIDENT—												
By Machinery												
By Falling or Slipping												
Being struck by Falling Objects												
By Use of Tool												
By Lifting												
By Burning or Scalding												
By Moving Vehicles												
Other Classes												
NATURE OF INJURY												
Head												
Eye												
Face												
Back												
Arms												
Hands												
Torso												
Legs												
Knees												
Feet												
Sprains Strains etc												
TOTAL												
NO OF DAYS LOST												

FIG 151 ANALYSIS OF ACCIDENTS FOR INFORMATION OF ACCIDENTS ADVISORY COMMITTEE

of children's allowance. In case of dependants partly dependent upon the earnings of the deceased the lump sum shall not exceed the above amount, but may be determined by arbitration to arrive at a reasonable sum.

In addition to the above an allowance is given for children who were wholly dependent upon the deceased, and the amount arrived at is calculated upon the deceased's earnings, and based on the ages of the children up to the time of their attaining to 15 years of age. In any case the total amount payable in the event of death shall not exceed £600 including both dependants' and children's allowances. If the workman leaves no dependants, the lump sum shall be an amount equal to the reasonable expenses of his medical attendance and burial, not exceeding £15.

Accident Advisory Committee

Every factory should have its own accident advisory committee, preferably a small one. The chairman should be a member of the managerial staff, and the secretary a member of the personnel department. The other members should include the head foreman of the shop, a member of the shop committee, and a qualified ambulance man from the shop where the accident has occurred. Such a committee can achieve much useful work. Tabulated information of the type shown in Fig. 151 should be placed before the committee and recurrent cases analysed.

CHAPTER XII

THE LARKIN SYSTEM OF WORKSHOP TRAINING

Introductory

It is only during recent years that closer attention has been paid by various authorities to the systematic training of apprentices.

It will be generally admitted that the training of those apprentices who normally become craftsmen on completion of their apprenticeship is frequently conducted on more or less haphazard lines even in what may otherwise be regarded as well-organized workshops, and at the best often leaves much to be desired. Seldom, if ever, does the apprentice know where he is destined to arrive either during or at the end of his apprenticeship, and although in certain cases he may be fortunate with his training, he is often decidedly the reverse.

Another undesirable fact is that when boys are placed in a workshop those showing special ability are, on account of their usefulness and industry, very often retained for some time on a particular section instead of obtaining experience in other sections of the shop. The inevitable result is that they complete their time without proper training in certain all-important aspects of the work. Other boys with less ability, who contrive to make nuisances of themselves, are thereby benefited by being passed on from one section to another. There are some too who are, as often as not, destined to follow a trade for which they are wholly unqualified and unsuited.

It is sometimes said that the apprentice of the modern factory is not nearly so well qualified as his predecessor; that, owing to mechanization and specialization, the former's training is necessarily a limited one, which leaves him incapable of taking on elsewhere, with any degree of assurance, the craftsman's job for which he is regarded as having been trained. Unfortunately this is frequently true, but, as will be explained, if a well-planned training system is employed, it is possible to provide the apprentice of to-day with a training superior even to that of his predecessor. Whatever scheme is adopted it should be self-organizing, otherwise the control of a large number of apprentices is a laborious undertaking.

Many are apt to think that the only thing which matters is the quickest and cheapest method of getting a job satisfactorily done. This is not so, as much thought should also be given to the training of the apprentice, on the completeness of whose practical experience his future, and incidentally that of the engineering profession, depends.

Equal Opportunities Essential

Every works should aim to give all its apprentices an equal chance within

the limits of the factory. An ideal course for one apprentice at the expense of another is to be wholly deprecated. The Larkin system can be claimed to be the only one which will give everyone in each grade the same opportunity of gaining experience. This is achieved by allotting a definite time to each particular section, the application of the system being made dependent on—

(1) The normal number of apprentices required in the shop.

(2) The agreed time to be spent in the shop.

(3) The actual number required on each section.

Any deviation from this principle will inevitably give someone a better chance at the expense of another.

A further advantage is that the needs of production, so far as apprentice work is concerned, are best met by the Larkin system, as new entrants will come in at prearranged intervals of time, and the flow of both apprentices and work will thus be consistently uniform.

This system of workshop training was evolved by the author towards the end of 1931. It represented an entirely new departure in training schemes and is built up on the assumption that continuity of work is required, i.e. that the flow of work is regular, and that no interruption of this can be allowed.

In addition to being logically sound, the system is believed to be unique. It is certain that no other system is so completely impartial, and its application will greatly enhance the reputation of any works' organization.

Whilst it is appreciated that the application of this system must of necessity differ at every works to suit particular requirements, the principle involved can be readily applied anywhere.

Before explaining the system in detail it may be helpful for others concerned with training, and in any case will not be without interest, to relate how it was evolved.

Difficulties where No System Exists

Soon after the author was appointed to supervise the affairs of some 600 apprentices, he was forcibly struck with the amount of time taken up in dealing with personal applications for transfers. Every day there would be at least one who bewailed the fact that he was long overdue for a transfer and that he had seen his foreman, who had been unable to do anything for him. Each apprentice had to be questioned regarding the training already received, and in the absence of any permanent record other than that of the shop in which the apprentice worked, his account had to be verified, as best it could, by consulting the particular foreman concerned.

In order to minimize these complaints it was arranged for equal numbers of apprentices, say three or four at a time, to be transferred from one shop to another. The arrangement was not above criticism—and needless to say received it!—yet in the circumstances it appeared to be the best solution to the problem. To say the least, it was "hit or miss" from beginning to end, and the one who did the most "shouting," and who possibly

managed to get the most varied experience, was not necessarily the most deserving candidate. Quite apart from this aspect, another thing with which to contend was what then appeared and still appears to be the almost universal practice observed when apprentices are engaged. This general practice is for an apprentice to be started when a craftsman leaves the service for any reason—a system which has no logical basis. The disparity between a craftsman's normal length of service as a craftsman and that of an apprentice as an apprentice is very marked, the lengths generally being in the proportion of 7 to 1.

It will thus be seen that for the foregoing arrangement to work satisfactorily there should be seven times as many craftsmen as apprentices, yet in actual practice this is not usually desirable and therefore probably never happens. Consequently it is not surprising to learn that sooner or later a foreman found it imperative to send in a "requisition"' for a number of apprentices. As one might expect, this was done at irregular intervals, with the result that it was not uncommon for as many as six apprentices to be started in some of the bigger shops at the same time. Quite obviously this was not a sound arrangement, because in the first place the work was either being held up or else it was being done uneconomically by adult staff; and, secondly, there was a considerable amount of unproductive training, with its consequent disadvantages, taking place at the same time.

There is another disconcerting feature which has appeared all too often. Although certain shops have little scope to offer, it has been the misfortune of many a bright young man (one questions whether he would be as bright at 21!) to commence and complete his apprenticeship with only one or, at the most, two moves. These various points are specially stressed because they appear to be common in works of all kinds. Hence it was not surprising that the whole position was very much to the fore in the writer's mind, and every workable channel which might conceivably offer a real solution was thoroughly explored.

Coding of Sections

To begin with, every section in each shop was suitably coded, and a chart, which will be more fully explained later, was prepared for recording in convenient form the training received. It was subsequently ascertained how many apprentices were normally engaged on each section. This, in turn, led to the realization that in order to maintain the correct number on the section, and pass on at the right time an apprentice from one section to another, there must be a definite relationship between the time spent and the number employed on the section.

What was this relationship? After all, it would be easy to arrange an ideal workshop course for the individual if the needs of production were ignored, more easy still perhaps if the shop staff was small, but such an ideal course would inevitably lead to intermittent work—a thing incompatible with economic production. The apprentice is an integral part of the

organization and must accordingly give the required output in addition to acquiring knowledge of his trade.

Equal Periods of Training for All

It was realized that it was necessary for each shop to have a uniform period between successive apprentices entering the shop, depending on the number required in the shop as well as on a definite limiting total period in the shop. It is important to stress these two points because it followed from these that the period on each section was dependent on the number employed on the section and was equal to or a multiple of the period between two apprentices entering the shop. And so it was that the system which the author has named "The Larkin System of Progressive Training," in view of the apprentice automatically progressing from section to section at predeterminate intervals of time, came into being to the immediate advantage of several hundred apprentices.

Fundamental Principles

Unless the circumstances are exceptional, there is no reason why an apprentice should not receive a proportionate amount of training on every section of the shop in which he is engaged. In other words, every apprentice should be given an equal opportunity and, as already stated, the key to this arrangement is that, having once decided on the average period to be spent in a particular shop, the length of training to be given on each section in that shop is directly proportional to the number employed on the section compared with the total number of apprentices in the shop.

Let us take a simple hypothetical case, as shown by Fig. 152. If there are fifty apprentices in a shop of three main sections, A, B, and C, where it is desired to give a total of five years' training, and on section A there are twenty-five apprentices, on section B

Section	No. of Apprentices Required	Proportion of Total Time in Shop	Actual Period on Section
A	25	$\frac{25}{50}$	$2\frac{1}{2}$ years
B	10	$\frac{10}{50}$	1 year
C	15	$\frac{15}{50}$	$1\frac{1}{2}$ years
Totals	50	$\frac{50}{50}$	5 years

FIG. 152. PLANNING OF TRAINING COURSE (HYPOTHETICAL CASE)

ten apprentices, and on section C fifteen apprentices, then each must spend $\frac{25}{50}$, $\frac{10}{50}$, and $\frac{15}{50}$ of five years respectively; or $2\frac{1}{2}$ years, 1 year, and $1\frac{1}{2}$ years on the three sections, to achieve the desired object. Any attempt to deviate from these periods will quite definitely result in continuity of work being broken down, or alternatively will give one individual a better training at the expense of another.

It may, of course, be suggested that because certain work calls for considerable skill, and is experience to be desired, an apprentice should have a longer period on it than on other work which is less skilful and where the experience gained is not so valuable. Unfortunately such an arrangement can only be applied where the greater volume of work coincides with the more skilful job. The normal volume

of work must always be the determining factor in fixing the period to be spent on any section, notwithstanding the experience value of the latter. It is most important that this fundamental fact should not only be grasped, but put into practice, otherwise the training system cannot possibly be satisfactory.

It should be appreciated that in whatever shop an apprentice may be started, or to which the apprentice is being transferred, an age limitation should be strictly adhered to, as necessitated by the principle of the scheme, apart from any question of the candidate's suitability for a particular trade.

Seniority by age, and not length of service, should be the governing factor, on conclusion of a six months' minimum period, for a trade apprentice to leave the initial stage in the shop which is regarded as the commencing point for the majority of the apprentices, thus preventing the older apprentice, who possibly has attended a central or a secondary school until attaining to the age of 16, from being in any way penalized. The movement of apprentices at the initial stage should be controlled by a schedule board, on which, after the first six months, the names are arranged in order of age with one hook for each apprentice's card.

The Larkin System in Operation

Consider first the case of a coppersmiths' shop where a minimum apprenticeship of five years is necessary in order to conform to trade requirements, and where, say, a total of eleven apprentices is required. The progressive interval between successive apprentices entering the shop should, therefore, be $\frac{5}{11}$ of a year, which equals $5\frac{1}{2}$ months. To simplify matters, six months should be substituted for $5\frac{1}{2}$ months, thus making the apprenticeship 11 $\frac{1}{2}$ year, which equals $5\frac{1}{2}$ years. In other words, the apprentice coppersmith must commence in the coppersmiths' shop at not more than $15\frac{1}{2}$ years of age.

Assuming four distinct sections in the shop, the position will be as shown in Fig. 153.

Code Ref	Description of Section	Number of Apprentices Required	Proportion of Total Time in Shop	Actual Period on Section Yrs	Mths
C1	Small Pipe Work	4	$\frac{4}{11}$	2	
C2	All Classes of Pipe Work	2	$\frac{2}{11}$	1	
C3	Bending to Templots, Welding Small Pipes	4	$\frac{4}{11}$	2	
C4	Sheet Metal Work	1	$\frac{1}{11}$		6
	Totals	11	$\frac{11}{11}$	5	6

FIG. 153. PLANNING OF APPRENTICE COPPERSMITHS' COURSE

Fig. 154 illustrates the type of chart which should be framed and posted in the shop where it can be seen by all concerned, a framed copy also being placed in the foreman's office adjacent to the schedule board.

Scheme for Erecting Shop

Consider next an erecting shop where the class of work is generally fairly heavy, and may vary between a somewhat rough class of job and a highly skilled one. It is essential that the selected apprentice must be growing up into a young man and already have had some experience at the bench. For this reason, a suitable apprentice should be selected from the fitting shop, or similar shop, who has received the desired training and is not more, say, than 18 years of age, thus giving him three years before completing his apprenticeship and ensuring that he has sufficient time to enable him to become an efficient erector.

The nature of the work in the erecting shop may be such that it is considered practicable to give training on all sections, provided that the ability of the apprentice warrants it. It may be, too, that there are as many as 18 separate sections, and as the total time to be spent in the shop is 36 months, the average period to be spent on each section is 36 months divided by 18, which equals 2 months. In such a shop the schedule board should be divided into weeks instead of months, as illustrated in Fig. 155, to enable the scheme to be worked more easily.

Code Ref.	Particulars of Work Done on Section	Period on Section in Years	Remarks
C1	Small Pipe Work . .	2	To be transferred from the Machine Shop at not less than 15 years and not more than 15½ years of age
C2	All Classes of Pipe Work . .	1	Transferred from Section C1
C3	Bending to Templets; Welding Small Pipes . . .	2	Transferred from Section C2
C4	Sheet Metal Work . .	½	Transferred from Section C3
	Total . . .	5½	

The period on each Section is dependent on the number of apprentices normally employed on the Section, and for that reason no departure will be made from such period. For the successful working of the scheme it will be necessary to start one apprentice on Section C1 every six months, and this arrangement will be ensured.

FIG. 154. APPRENTICE TRAINING SCHEME FOR COPPERSMITHS' SHOP

Working of the Training Scheme

The actual working of the scheme is simplicity itself, and should be carried out as follows—

A master schedule board, Fig. 156,

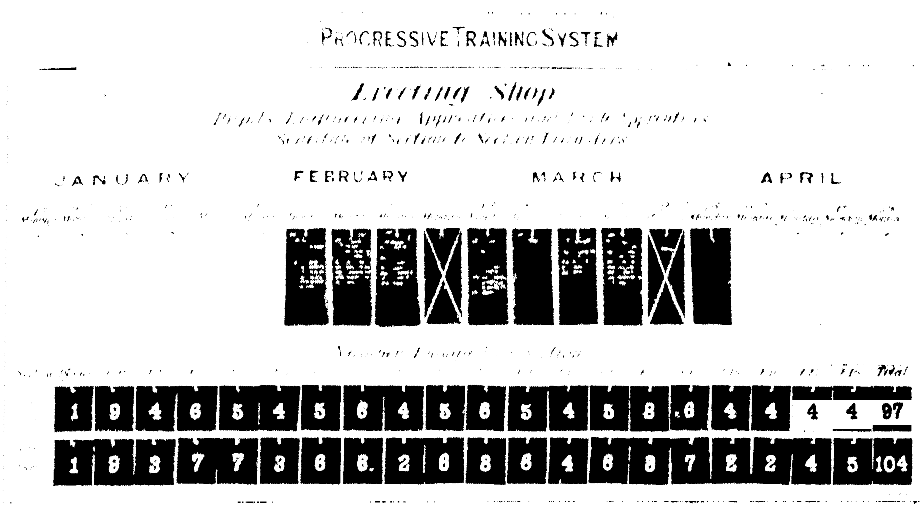


FIG 155 SCHEDULE BOARD DIVIDED INTO WEEKS

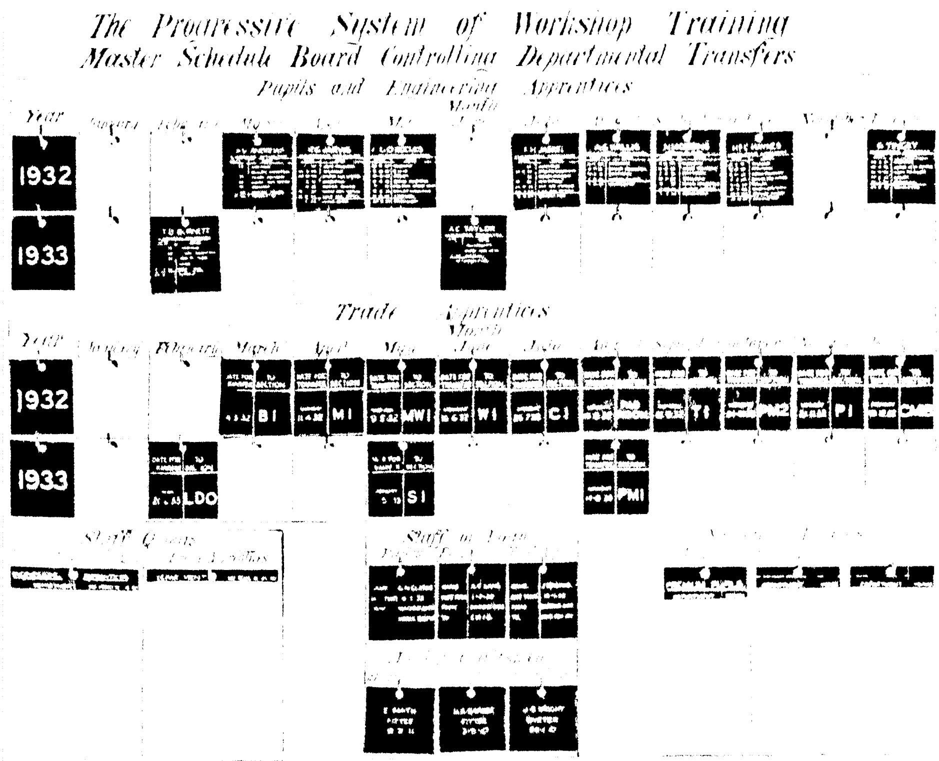


FIG. 156. MASTER SCHEDULE BOARD LOCATED IN STAFF OFFICE

should be kept by the personnel department to be utilized for operating shop-to-shop transfers. As will be seen, the arrangement of the board is such that it is divided into calendar months and covers a period of two years. A card, about 2 in. square, date on the card revised. The six-monthly transfer can then be forgotten until next March arrives, when the transfer is again carried out and the card moved forward to September. Thus, without any difficulty, the staff clerk controlling the master moves has

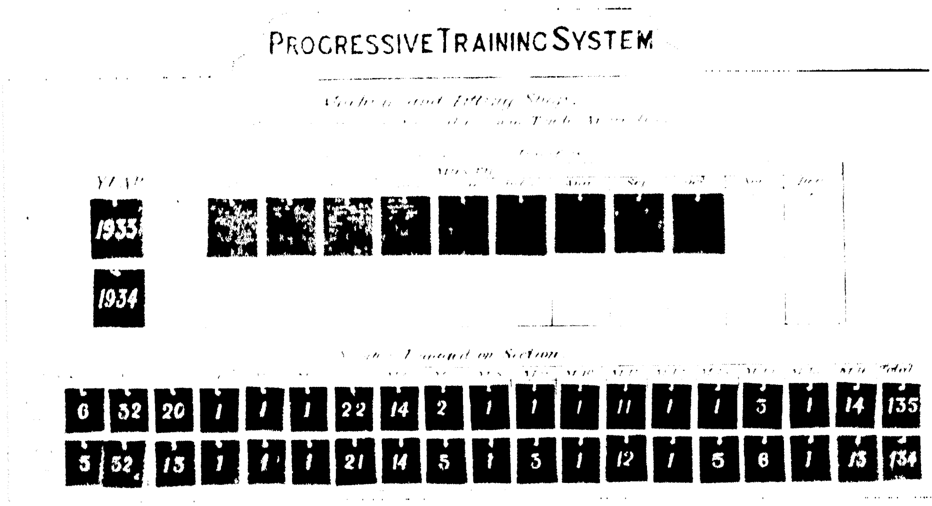


FIG. 157. SCHEDULE BOARD DIVIDED INTO MONTHS

should be used for each "master" move required, that is to say, for each move which involves a new entrant or a transfer from one shop to another. For instance, it may be that an apprentice is to be transferred from a certain shop to another shop every six months. The card will give these particulars without reference to any particular individual. Assuming that it is now September, and that the position of the card on the board coincides with that month, then the card will be moved forward on the board—as soon as the transfer has been effected—to March of the following year, and the a constant reminder of what transfers are required as each month comes along. A hinged glass front to the master board will minimize the possibility of the cards being displaced.

In the shops, section-to-section transfers will just as readily be carried out. In the foreman's office of each shop there should be a schedule board on which are placed, on similar cards to those used by the personnel department, all apprentices employed in the shop, each card bearing the name of one apprentice and showing the dates on which he is to be transferred to the various sections. The working of the

shop boards will be similar to that of the master board in the personnel department, the only difference being that with the one, shop-to-shop transfers will be controlled, this being done initially without reference to any individual, while with the other, section-to-section transfers will be effected in accordance with the prearranged schedule, the transfer being applicable to some particular individual. Fig. 157 shows such a board, the top portion being identical in principle to the master board used in the personnel department indicating the date when any particular individual is due for transfer. The bottom portion of the schedule board shows the normal quota required and the actual number engaged on each section. Underneath the card which gives the actual number engaged on the section is a card for every apprentice on the section, giving his name only; as the apprentice is moved, so this card is also moved. Thus the number of apprentice cards acts as a positive check on the number stated on the front card, which represents the actual number engaged on the section.

It will be observed from Fig. 155 that the shop board is shown subdivided into weeks, instead of months. This may be necessary owing to the frequency of the transfers from section to section. In the case of the smaller shops, where the apprentices are few and move less frequently, and possibly all together, the schedule boards used may be simpler still. They merely indicate the various stages and the apprentices engaged thereon, one card, instead of two, sufficing to control the movement of each apprentice. Such a board is indicated in Fig. 158.

Record of Training

A weekly return should be sent to the personnel department showing the progress of each apprentice who has

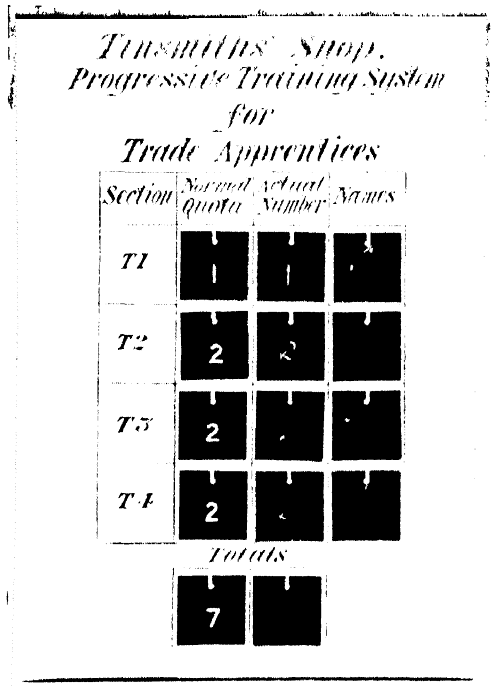


FIG. 158 SCHEDULE BOARD FOR SMALL SHOP

been moved to another section or shop, and the information recorded in an abbreviated manner on a standard training chart, Fig. 159. In this way the whole of the training received will be both systematically and readily recorded, and as these reports will come from various foremen who most probably are not aware of what has been sent in on a previous occasion, a very accurate and comprehensive record of the training given, the

NAME	BALL, CHARLES JOHN	BAKER JAMES CYRIL	BENSKIN RICHARD	BENTLEY ROY	BARKER ERNEST JOHN DEAN	BILLINGTON CHARLES EDWARD.	BILSON FRANCIS ALEC,	BOWDEN JOHN FREDERICK,	BULL WILLIAM JAMES,	BRITTAIN, CHRISTOPHER	BINNS SAMUEL.	BENTON JOHN DANIEL.
STAFF REFERENCE	C 404/9910	C 404/9937	C 404 9990	C 405/13	C 405 72	C 40[illegible] 142	C 405/108	C 405 305	C 405/365	C 405/366	C 405 387	C 406/400
DATE BORN	16 3 13	21 2 15	23 6 13	23 5 15	1 1 15	8 4 14	7 8 15	4 3 16	9 11 15	9 11 15	14 11 16	30 10 15
SCHOOLS ATTENDED	PEAR TREE COUNCIL	ALLENTON COUNCIL	CITY OF LEEDS SECONDARY	C OF E SCHOOL SWANWICK	TRAFFIC ST DERBY	ST JAMES CHURCH CENTRAL CLASSES	PEAR TREE COUNCIL	NOTTINGHAM RD DERBY	BRIGHTON RD DERBY	GERARD ST DERBY	JUNIOR ART SCHOOL DERBY	WEST HALLAM NOTTS
FORM or STD REACHED	7/7	7/7	4/6	8/8	x7 x7	IV V	7/7	III B/III A	III A III A	x7/x7	V VI	x7/x7
SUPT of APPREN REMARKS	INTELLIGENCE MODERATE APPEARANCE GOOD	A PARTICULARLY GOOD CANDIDATE	INTELLIGENCE V GOOD	INTELLIGENCE FAIR	INTELLIGENCE -GOOD	INTELLIGENCE GOOD	VERY WELL BUILT INTELLIGENCE GOOD	INTELLIGENCE FAIR APPEARANCE GOOD	INTELLIGENCE GOOD	INTELLIGENCE V.GOOD	A PARTICULARLY GOOD CANDIDATE	INTELLIGENCE -FAIR
DATE EMPLOYED	21 5 29	6 6 29	25 7 29	26 7 29	19 9 29	15 11 29	12 12 29	29 5 30	19 6 30	19 6 30	21 8 30	28 8 30
PERIOD OF APPRENTICESHIP	4 10/12 YEARS	6 8/12 YEARS	4 11/12 YEARS	6 10/12 YEARS	6 3/12 YEARS	7 5/12 YEARS	6 8/12 YEARS	6 9/12 YEARS	6 5/12 YEARS	6 5/12 YEARS	6 3/12 YEARS	6 2/12 YEARS
TERMINATION OF APPRENTICESHIP	15 3 34	20 2 36	22 6 34	22 5 36	31 12 36	7 4 35	6 8 36	3 3 37	8 11 36	8 11 36	13 11 36	29 10 36

	BALL				BAKER				BENSKIN				BENTLEY			
	DATE	SECTION	ABILITY	ATTEN TO DUTIES	DATE	SECTION	ABILITY	ATTEN TO DUTIES	DATE	SECTION	ABILITY	ATTEN TO DUTIES	DATE	SECTION	ABILITY	ATTEN TO DUTIES
INITIAL PLACING	21 5 29	B1	A	G	6 6 29		VG	VA	26 7 29	M1	A	M	26 7 29	M1	A	M
1 TRANSFER	7 12 30	B2	A	G	20 2 30	M1	A	VA	20 2 30	M11	A	G	20 2 30	T1	A	VA
2 "	6 9 31	B3	VG	G	9 9 30	M6	VG	G	4 11 30	M4	A	G	23 11 30	T2	A	VA
3 "	9 1 31	B4	A	G	22 6 31	M7	VG	VA	27 8 31	M8	A	VA	10 6 32	T3	A	G
4 "	26 6 32	B5	VG	VA	1 3 32	M5	A	VA	3 5 32	M9	VG	G	20 11 33	T4		
5 "	11 12 32	B6	A	VA	10 2 33	M16	VG	G	10 2 33	M12	VG	G				
6 "	26 6 33	B9	A	G	23 10 33	PROMOTED	TO		27 6 33	M6	A	G				
7 "	2 10 33	B11	VG	G	ENGINEERING		[illegible]		22 6 34	TO FITTER						
8 "	11 12 33	B12	VG	G												
9 "	15 3 34	TO RIVETER														
10 "																
11 "																
12 "																
13 "																
14 "																
15 "																
16 "																
17 "																
18 "																
19 "																
20 "																
21 "																
22 "																
23 "																
24 "																
25 "																

	BARKER				BILLINGTON				BILSON				BOWDEN			
	DATE	SECTION	ABILITY	ATTEN TO DUTIES	DATE	SECTION	ABILITY	ATTEN TO DUTIES	DATE	SECTION	ABILITY	ATTEN TO DUTIES	DATE	SECTION	ABILITY	ATTEN TO DUTIES
INITIAL PLACING	19 9 29		A	VA	4 11 29		VG	VA	12 12 29	PR	A	VA	29 5 30	M1	A	M
1 TRANSFER	24 3 30	M1	VG	G	8 9 30	M1	A	VA	5 8 30	M1	A	VA	2 2 31	M1A	A	G
2 "	14 12 30	PM1			15 3 31	BM1	A	VA	2 9 31	M8	A	G	2 [illegible] 31	M10	A	VA
3 "					5 5 33	BM2	VG	VA	2 [illegible] 31	M	VG	G	29 8 32	W1	VG	VA
4 "					2 10 33	BM3	VG	VA	2 1 32	M3	VG	G	10 2 33	W2	A	VA
5 "					29 [illegible] 34	E4	A	G	7 3 32	M5	A	M	7 5 34	W3		
6 "					15 3 34	E7	VG	G	3 5 32	M7	VG	G				
7 "					7 6 34	E12	A	VA	29 8 32	M6	VG	G				
8 "					6 9 34	E10			[illegible] 2 32	M9	A	G				
9 "									3 3 33	E1	VG	G				
10 "									7 8 33	E2	VG	VA				
11 "									12 3 34	E2	VG	G				
12 "									3 9 34	W50						
13 "																
14 "																
15 "																
16 "																
17 "																
18 "																
19 "																
20 "																
21 "																
22 "																
23 "																
24 "																
25 "																

	BULL				BRITTAIN				BINNS				BENTON			
	DATE	SECTION	ABILITY	ATTEN TO DUTIES	DATE	SECTION	ABILITY	ATTEN TO DUTIES	DATE	SECTION	ABILITY	ATTEN TO DUTIES	DATE	SECTION	ABILITY	ATTEN TO DUTIES
INITIAL PLACING	19 6 30	S1	A	VA	19 6 30		VG	VA	2 8 30		A	VA	28 8 30		A	G
1 TRANSFER	8 12 31	S2	A	VA	5 3 31	M1	VG	G	[illegible] 6 31	M1	VG	VA	17 6 31	P1	A	G
2 "	26 6 33	S3			2 11 31	M15	VG	G	11 12 31	M6	VG	VA	10 6 32	P2	A	G
3 "					7 8 32	M16	VG	VA	29 8 32	MW2	A	VA	10 2 33	D3		
4 "					8 5 33	M9	A	VA	27 11 33	MW3						
5 "					9 3 34	M11										
6 "																
7 "																
8 "																
9 "																
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25 "																

	BALL	BAKER	BENSKIN	BENTLEY	BARKER	BILLINGTON	BILSON	BOWDEN	BULL	BRITTAIN	BINNS	BENTON
EVENING CLASSES ATTENDED	DERBY TECH COLLEGE SHEET & PLATE METAL WK YEARS 1 2 & 3.		DERBY TECH COLLEGE ORDINARY NATIONAL CERT IN MECHANICAL ENG.									
GENERAL REMARKS	SUITABLE FOR PLATER		GOOD TYPE OF CRAFTSMAN									
SUPT of APPREN RECOMMENDATIONS AT 21 YRS OF AGE	TO BE RETAINED		TO BE RETAINED									

Fig 159. Record of Training Chart

progress made, and the present location of every apprentice, will always be available. Alternatively, a card system can be adopted, one card being used for each apprentice.

The main point is that every works should have a permanent record of the work done by each apprentice. It may be required at any time in connection with promotions, for reference or disciplinary purposes, or even for dealing with a complaint from the apprentice himself. No one could ever prove that it was right to ring up the various shops to ascertain what training an apprentice has been given and what progress he has made. Nor is it desirable even that the suggested card record should be passed from one shop to another for the shop clerical staff to enter the record, because an impartial report is required, uninfluenced by what has gone before. It is essentially a staff record which every well-organized works will keep.

Method of Recording Progress

The formula shown in Fig. 160 is suggested for reporting on the progress and ability of apprentices each time a move is made from one section to another. Apart from reducing the clerical work to a minimum it will ensure a definite standard from which comparisons can be made, and will eliminate the complications which occur if long, dissimilar remarks are given. These reports will be especially valuable in deciding whether or not the apprentice is worthy of retention as a craftsman on reaching 21 years of age. When it is not possible to report on an apprentice on these lines, the remarks which it may be necessary to give will serve the purpose of drawing special attention to any individual. For instance, if the progress of an apprentice is so poor that he cannot be classed as either fair or moderate, the remark "Poor" will have to be inserted in full in the appropriate column.

Ability	Code Ref	Attention to Duties	Code Ref
Very Good	VG	Very Attentive	VA
Average	A	Good	G
Fair	F	Moderate	M

FIG. 160. CODE FOR RECORDING STANDARD OF EFFICIENCY
(Giving nine combinations)

Flexibility of System

If an alteration in the flow of work in any particular shop necessitates a revision in the number of apprentices required on any of the sections, or in the total number in the shop, the chart (Fig. 154) which controls the training course can readily be amended to suit the new conditions, and the necessary adjustment will then become automatic.

In the belief that the system outlined is the ideal, and that it is well in advance of any other, the author unhesitatingly commends it to all associated with the training of apprentices and kindred grades.

Brief reference should here be made to the very definite need for every trade apprentice to undertake a systematic course of part-time day and/or evening classes throughout his apprenticeship. No craftsman can carry out his duties efficiently if he is unable to understand and read a drawing or to work out a simple arithmetical problem when the necessity arises. Generally it is the one who possesses a little more than average knowledge who is selected for a higher position, and whilst it is not at all certain that any theoretical knowledge gained will ensure his getting a supervisor's job, it is definite that he will not be given the splendid opportunity if he has not acquired that essential knowledge.

CHAPTER XIII

THE EMBRYO ENGINEER

OPINIONS differ widely as to how a mechanical engineer is best trained. Much has already been said on the subject and previous writers have pronounced their considered verdicts. May the author, however, now state the case as he sees it, having for several years in the past interviewed as many as 250 pupil and apprentice applicants per annum, some of whom were from the humblest out-of-the-way elementary schools, whilst others came direct from public schools and from universities.

Many fathers think, because their sons are interested in the hobbies of the average boy, that those sons are mechanically minded. In reality, if the growing boy is keenly interested in his model engine, his meccano set, or his so-called scientific puzzle, it merely indicates that he is developing his brain in a perfectly orthodox manner. Not every such boy is destined to become an engineer. From personal observation it has been found that few boys really know what they desire to become. Generally, indeed, they have no conception as to what is implied by the various professions and vocations. Except, therefore, in isolated cases, which latter are readily distinguishable, one should not attach too much importance to the spare-time pursuits of the average boy whilst at school.

Essential Qualities

In the author's opinion a satisfactory candidate needs to be both studious and practical. By "studious" it is implied that he should have a natural aptitude for any of the sciences, and more particularly for mathematics, the latter being the very essence of logical and deep-seated thought, a quality so essential to the successful engineer. The word "practical" implies the desire to reason out the why and the wherefore of anything which may come one's way, and not merely to take it all for granted; a desire to make a really good job of anything to be done whether it be at school or outside; above all, the power to be methodical.

As in everything else it is possible to meet the exception to this rule, yet broadly speaking any boy who conforms to the description given is a likely candidate for the engineering profession. He has at least the right temperament, and his innate ability will slowly but surely reveal itself as he gains experience.

Theoretical Aspect

It will be convenient to consider first the theoretical requirements of an applicant. In these days of higher education and greatly enhanced facilities for acquiring knowledge, it cannot be considered that any boy of

normal intelligence and physique has justified his existence if he has attended a secondary school or public school until he has attained to 16 years of age, and yet has not matriculated or obtained the school certificate as set out in Fig. 161. It is certainly

SUBJECTS OF EXAMINATION

English.
Foreign Language.
Elementary Mathematics

Mechanics Physics Chemistry Mathematics (more advanced) Geometrical and Mechanical Drawing	Any two of many optional subjects, of which these five are the most suitable for an engineering career

FIG 161. MATRICULATION AND SCHOOL CERTIFICATE EXAMINATIONS

desirable that every young man who wishes to become an engineer should have passed one of these examinations, or the equivalent, before proceeding with his engineering training. This latter may be divided into two sections—practical and theoretical.

Everyone is unanimous that practical training is an absolute necessity; indeed, the more the better! It is therefore the acquiring of the requisite amount of theoretical knowledge which is surrounded by so much controversy. Just how and when it should be obtained is the highly important question. Whether it is better for the embryo engineer to serve a comparatively short term, say of twelve months or of two years, in the workshops prior to his going to the university, with a view to his returning for a further period in the shops, is a vexed question, and one which to many seems to have no satisfactory solution. There is certainly a great danger in such cases that the young man, having experienced shop life with its heavy work and comparatively long hours, will not too readily settle down again after the minimum three years' course at the university. There is, too, the possibility of the management having changed to such an extent whilst he is at the university that on his return he finds the factory a very different place from when he left it, and not necessarily to his liking. Satisfactory results are sometimes obtained, however, by this procedure.

Pupilage or Apprenticeship

The ideal method, in the author's opinion, is for the candidate to go to a university direct from school and during the vacations to obtain practical experience with an approved firm. By working on these lines it is possible to obtain as much as four months' practical experience per annum. After graduating, the embryo engineer should take up a pupilage covering a period of from two to three years' workshop training. Such a candidate is thereby placed in a strong position and is more likely to succeed than any other. If, however, this arrangement is not possible, the part-time system is recommended, whereby a full apprenticeship is served, together with at least one full day and two evenings per week at technical classes. In this instance instruction is given to enable the candidate to sit, firstly for the ordinary national engineering certificate,

subsequently for the higher national engineering certificate, both issued by the Institution of Mechanical Engineers in conjunction with the Board of Education (as set out in Fig. 162), and still later to qualify in either the A.M.I.C.E. or A.M.I.Mech.E. examination, Figs. 163 and 164 respectively. This arrangement normally produces extremely good candidates, and it is not uncommon for a young man to take the degree course, as an alternative to the national certificate course, and even obtain an honours degree (Fig. 165).

Considering that the theoretical side of the question has now been adequately dealt with, the all-important question of the practical training comes to the fore.

Title of Certificate	Length of Course in Years	Subjects of Examination
		Typical Courses
Ordinary National . .	3	Mathematics. Applied Mechanics. I.C. Engines, or Heat Engines, or Workshop Materials and Processes. Physics.
Higher National . .	2	Properties and Strength of Materials. Electrotechnics of the Automobile, or Steam Theory and Practice. Engineering Design and Drawing. Fundamentals of Industrial Administration.

FIG. 162. CERTIFICATES IN MECHANICAL ENGINEERING
(Awarded by the Institution of Mechanical Engineers in conjunction with the Board of Education)

Practical Training

It is a *sine qua non* that the young man must be prepared to work—and work hard! He must not expect, because his father is Mr. So-and-So,

ASSOCIATE MEMBER OF THE INSTITUTION OF CIVIL ENGINEERS

Section	Subjects of Examination
A*	Mechanics. Strength and Elasticity of Materials. Electricity and Magnetism. Theory of Machines.
B*	Metallurgy. Theory of Heat Engines. Engineering Drawing.
C	Engineering Drawing. Specifications and Quantities.

* Exemption may be granted to the holders of the degree of B.Sc. in Engineering.

FIG. 163. ASSOCIATE MEMBERSHIP EXAMINATION, INSTITUTION OF CIVIL ENGINEERS

ASSOCIATE MEMBER OF THE INSTITUTION OF MECHANICAL ENGINEERS

Section	Subjects of Examination	
A	Part I. (*a*) Applied Mathematics. (*b*) Physics and Chemistry. Part II. (*a*) English Essay and Fundamentals of Industrial Administration. *or* (*b*) Modern Language (French, German, Italian, Russian, or Spanish).	
B	(*a*) Theory of Machines and Machine Design. (*b*) Properties and Strength of Materials.	
	(*c*) Steam and Steam Engines. Internal Combustion Engines. Hydraulics and Hydraulic Machinery. Electrotechnics and Mechanical Design of Electrical Machinery. Metallurgy. Aeronautics. Workshop Technology.	Any one subject.
C	Workshop Organization and Management.	

Note. Exemption may be granted in all Sections (A, B, and C) to holders of the Ordinary *and* Higher National Certificates, providing they have also qualified in (*a*) Physics, (*b*) English Essay and Fundamentals of Industrial Administration, (*c*) Workshop Organization and Management.

FIG. 164. ASSOCIATE MEMBERSHIP EXAMINATION, INSTITUTION OF MECHANICAL ENGINEERS

Stage	Subjects of Examination
Matriculation .	(Shown on Matriculation Chart, Fig. 161.)
Intermediate .	Pure and Applied Mathematics. Heat, Electricity, and Magnetism. Chemistry. Engineering Drawing.
Final — Part I	(1) Strength and Elasticity of Materials and Theory of Structures. (2) Theory of Machines. (3) Applied Heat and Mechanics of Fluids. (4) Applied Electricity. (5) Mathematics.
Final — Part II*	Applied Thermodynamics. Theory of Machines. Strength and Elasticity of Materials. Mathematics. Mechanics of Fluids. Surveying. Principles and Design of Electrical Machines. Electrical Power. Electrical Measurements and Measuring Instruments. Telecommunications. Theory of Structures. * Any four subjects.

FIG. 165. ENGINEERING DEGREE COURSE

who is familiar to all, that he will ultimately be found "a place near the sun." The idea may have held good in the past, but it is not so nowadays. He must prove himself a worthy candidate, and in the face of keen competition show by sheer merit that he is the only one for a particular job which may be vacant. If he does not work diligently he is in a precarious position on the completion of his all-round training, which by its very nature has not necessarily made him a good craftsman.

A general scheme for what may be regarded as an ideal workshop course will be outlined. The actual period to be spent in each department will depend primarily on the total period of shop training to be obtained, and secondarily on the availability of the various sections.

In arriving at this workshop course it has been assumed that the total number of pupils and engineering apprentices will be small compared with the total number of trade apprentices, otherwise the period on each section will need to be arrived at in a similar manner to that outlined in Chapter XII. As far as possible it should be part of the scheme to work in the periods of training for pupils and engineering apprentices along with those of trade apprentices. For this purpose it is considered to be immaterial which grade is doing the work.

The practice, which is known to be operative in some works, of allowing pupils and higher grades of apprentices to be "passengers" during their progress through the shops, can only be deemed unsound. After all, mere observation of workshop processes is not the best way to become familiar with them or to appreciate the difficulties which inevitably arise from time to time. For this reason the pupil should be regarded as an integral part of the productive group to which he is attached, and he should be expected to give an output not less than that of the average trade apprentice.

Machine Shop. Machine shop training is essential, and for most people will form an excellent starting-off point. In addition to the marking-out tables, a period should be spent on general turning, including screw cutting, as well as other types of modern machine tools. As every engineer knows, a tremendous amount of money is spent in producing machined components and one cannot pay too much attention to the various types of machine tools.

Fitting Shop. There should be an equally long period spent in the fitting shop as in the machine shop, and it should include a reasonable proportion of time in the tool room.

Pattern Shop. The young engineer might next be introduced to the pattern shop. He may not become expert in the use of all the patternmaker's tools, but after two or three months' experience he will at least appreciate the elements of patternmaking, e.g. the preliminary operation of setting-out, the allowances to be made for contractions and machining, the labour-saving expedients used for the provision of certain small radii, and the general principles underlying the correct assembly of patterns and core boxes.

Foundries. Training in one or other of the foundries should follow, preferably in the iron foundry. The mixing of sand, core-making (both dry and loam cores), plate, machine, and floor moulding, are all of first importance. There are, too, the fettling and sand blasting sections of the foundry, each with its special problems.

Erecting Shop. The erecting shop always has a strong appeal, and is often regarded as the most suitable department in which to complete a workshop training. It is certainly true that, after having served in all other departments, one can better appreciate what is involved in preparing the various units for the erecting shop.

Additional Workshop Training

It is not suggested for one moment that the training which has been outlined is exhaustive. It does, however, provide the essential foundations, which can be extended if the period available is sufficiently long to permit of additional training. Such addition might include a course in the millwrights' shop where all classes of machine repairs are carried out, in the electric shop where the motors are repaired, in the materials testing department, or on one or more of the rapidly expanding welding sections. In the manufacture of many products there is an increasing demand for mechanical-electrical engineers, and therefore, if six months or so can be spent on electrical manufacturing work, such experience will undoubtedly prove most advantageous.

No doubt most young men have their own ideas as to what constitutes an ideal course, and possibly a modification of the training laid down can, in certain instances, be carried out with advantage. It should be realized, however, that the principle of any particular subject can only be mastered by much concentrated study; accordingly too frequent transfers are to be avoided.

The author well remembers seeing the pointed reply of an eminent engineer to a father who had written to him saying that his pupil son did not consider he was being moved round the works quickly enough. The letter ran as follows: "I gather from your letter that your son thinks that he has not been having a sufficiently wide experience during the six months he has been with us. It appears to me, however, that he is like a good many other young men of the present day and wishes to run before he can walk, if he was learning to play the piano he would be engaged for a long period of his time practising the scales before tackling the compositions of Mozart. In my view one of the essentials for a young engineer is that he should be well grounded in the fundamentals of his profession, and this means application to what appear to be minor operations."

Office Training

In the case of pupils, it is most desirable that, at some convenient period of the workshop course, three to four months should be devoted to training in one or other of the several administrative offices connected with the works. It is immaterial whether it be the estimating office, the central

planning office, or the progress office, any one of which will clearly reveal that there is "another side to the picture." To the inquiring mind fresh avenues of thought will be opened, and such training will prove beyond any shadow of doubt that the administrative staff is of first importance, and that, by careful scrutiny of existing practices, it is in a position to save probably more money than the designing staff or the shop foremen.

Drawing Office Experience

Drawing office training is most desirable for the complete mechanical engineer, but if the young man who is privileged to enter the drawing office for a short course thinks he is going to design an aero engine, a machine tool, or an overhead travelling crane, or for that matter any important part of one of them, he will be hopelessly disillusioned. It never was so and never can be! At the best, he can only aspire to evolving some insignificant detail. An intimate knowledge of design, to which every intelligent young engineer aspires, can only be gained in the hard school of experience. The best advice that can be given to him, therefore, is to discover the origin of, and the reasons for, any new design, to follow up its development, to familiarize himself with the make-up of each type of arrangement and detail drawing, the preparation of the prints required and their issue to the appropriate shops, the drawing up of specifications and the ordering of certain materials, the registering of drawings, and the manner in which alterations are recorded and the shops advised. These are some of the ways in which the young man, who has only three months, or at the most six months, allotted to him for his course in the drawing office, can use that time to the best advantage.

(In the writer's opinion the ideal place for the drawing office course is at the end of the practical training, and should preferably take place when the apprenticeship or pupilage is concluded.) It is then that the embryo engineer can best appreciate and absorb drawing office practices.

Suggested Training Scheme for Higher Grades

Three distinct grades are suggested, and these will be considered in ascending order of importance—

1. *The Engineering Apprentice.* The applicant should be over 16 and under 18 years of age on admission, and should usually have attended a secondary school or a public school, his theoretical qualification being matriculation, or the school certificate with a credit in mathematics. If already a trade apprentice, however, he may be promoted to the grade of engineering apprentice if warranted by his general progress in the shops and at evening classes, and by his personality always having due regard to his age. The workshop course should cover most of the principal shops, and in addition attendance at day classes should be permitted for one full day a week. Wages should be paid in accordance with the scale laid down for trade apprentices. In all cases engineering apprentices should complete their apprenticeship at 21 years

of age, future employment being dependent on what vacancies may occur, and also on the ability of the individual concerned.

2. *The Premium Pupil.* He should be required to pay a premium, he should usually be over 21 and under 24 years of age on admission, and as far as possible he should be a university graduate. The pupilage should cover a period of two years, nominal wages being paid on the actual time worked. It is a quite workable scheme for the premium to be paid back in wages during the first year of service. As in the case of engineering apprentices, one day per week should be allowed for attendance at classes, the courses taken being dependent on whether or not the pupil has already obtained a degree. A study of metallurgy and metrology is suggested for those who have obtained a degree. The standard workshop course should cover every important section, and if some vocational training has previously been obtained the course should be extended to the jig and tool drawing office.

3. *The Engineer Pupil.* This is the highest of the junior grades recommended, and as such will be highly coveted. The requirements should be unmistakably of a high standard. In addition to having obtained an honours degree, the candidate should possess a distinctive personality. The age limit should be similar to the premium pupil, but the course should extend over a period of three years. No premium should be required, but a wage should be paid similar to that of the premium pupil. For the first two years the standard workshop course should cover the same ground as that of a premium pupil, which is regarded as the ideal for the period available. If previous experience has been obtained in certain work, the opportunity should be given to widen the field of training by allowing the engineer pupil an equivalent period in the engineering research and development section, a highly specialist branch of work which will probably operate under a research manager. During the third and last year, training should be given in the stores controller's office, the works and costs accountants' offices, and in one of the more important works' offices, in three equal proportions.

It will thus be seen that with this grade every facility should be given for acquiring knowledge in those all-important sections with which the mechanical engineer is inseparably associated. Especially noteworthy is the period spent in the accountant's department. It is a suggestion which has everything to commend it. The introduction of individual costing, accelerated by the advent of mechanized equipment, has greatly developed the costs and statistical sections, and by actual contact with those permanently engaged therein a valuable insight into the methods used in providing important data, financial and otherwise, and the ultimate practical uses to which such information may be put, will be gained.

The chart shown in Fig. 166 illustrates the suggested training for the three grades to which reference has been made. The premium pupil should

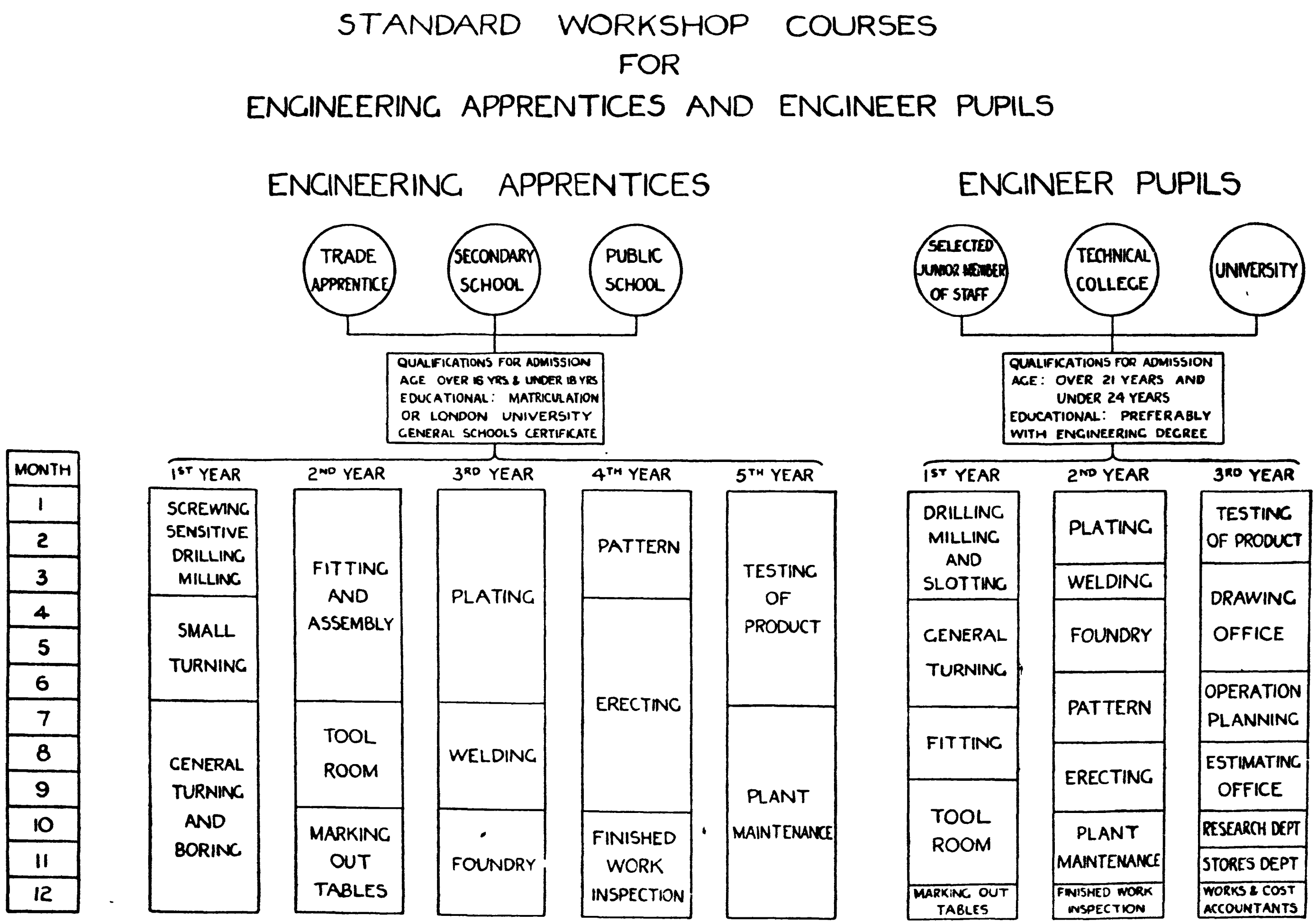


Fig. 166. Workshop Courses for Higher Grades

only be allowed the first two years of the engineer pupil's course.

Transfers should be controlled by the schedule boards which were referred to in the previous chapter. Similarly, a training card should be used in the shop for recording progress and ability, this information being transferred to the record maintained by the personnel department.

Personal Requirements

If the young man has taken full advantage of the facilities which have been afforded him he should be well on the way to a successful career. To be successful, however, he must have self-confidence, energy, and initiative. He must be patient and thorough; he must show a distaste for waste and a keenness for efficiency; he must be willing to entertain new ideas and progressive schemes. He must get a true conception of every job which he is given, and he must not over-estimate his own importance and under-estimate that of his rivals. He will, of course, have his ideals, and in carrying them out he may inevitably offend at times but will certainly please at others. Above all, he should deal with any subordinate staff as he would have his superiors deal with him, and he should at all times be guided by the age-old maxim: "It pays to play the game."

Experience is not what happens to a man; it is what a man does with what happens to him.

ALDOUS HUXLEY.

CHAPTER XIV

TIME RECORDING

Unpunctuality

ALTHOUGH every employer knows how easy it is for an employee to lose five minutes a day, he does not always appreciate the cumulative effect of this loss. Five minutes lost per day by an employee paid at the rate of 1s. per hour equals a productive loss of 1d. per day. If working a $5\frac{1}{2}$-day week it equals $5\frac{1}{2}$d. per week, and if working 50 weeks per year it equals roughly £1 3s. On this basis Table XIV shows the cumulative productive loss per annum.

Time Recorders

The most satisfactory way of recording the time worked by employees is by means of electrically controlled time recorders. There are several reliable makes of time recorders on the market, but whatever type is decided upon as standard it should at least conform to the following general specification—

(1) It must be of convenient size and robust construction.

(2) It should be of the type which uses independent cards, otherwise if a chart is used to cover a number of employees the time clerk is unable to see at a glance which employees have arrived late and also whether any have failed to report for duty. Further, a chart can only be dealt with by one wages clerk at a time.

(3) It should permit of one-hand operation (Fig. 167).

(4) The clock face should be visible both to operators registering on the recorder and to persons standing at a distance.

(5) The card receiver, registering handle, and clock face should be close together, and all in the direct line of vision of the person registering.

(6) The inspection cover should be easily detachable to facilitate cleaning, ribbon changing, and similar work.

TABLE XIV

CUMULATIVE PRODUCTIVE LOSS DUE TO UNPUNCTUALITY

Rate per Hour	Number of Employees				
	1	10	25	50	100
s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.
1 0	1 3 0	11 10 0	28 15 0	57 10 0	115 0 0
1 3	1 8 9	14 7 6	35 18 9	71 17 6	143 15 0
1 6	1 14 6	17 5 0	43 2 6	86 5 0	172 10 0
1 9	2 0 3	20 2 6	50 6 3	100 12 6	201 5 0
2 0	2 6 0	23 0 0	57 10 0	115 0 0	230 0 0

FIG 167. TIME RECORDER PERMITTING OF ONE-HAND OPERATION

(7) The mechanism should be easily removable (Fig. 168).

Not only time recorders, but if possible all works' and office clocks, should be electrically controlled and should be synchronized with a self-regulating master-clock suitably located in the personnel department, in order that a check may be made at least once a day with Greenwich or other standard time.

Motorized Time Recorder

The more recently marketed motorized recorder will commend itself to all concerned with time recording. As will be seen in the illustration (Fig. 169), the grouping of all important features is centralized at the top of the machine. Colour printing indication and column indication are visible to the employee when making his record. and with the "direct read" time indication, time can be quickly read. When a card is inserted in the receiver a trigger is tripped immediately the card reaches the correct position, thus the printing hammer which is kept "cocked" is released, printing the time registration in the correct space, the power unit then "re-cocking" the hammer. The machine is capable of 110 records per minute, there being no levers whatever for the employee to manipulate. Another decided advantage is that the clocking is carried out on the front of the card. Because of the automatic operation

FIG. 168. TIME RECORDER ILLUSTRATING EASE WITH WHICH MECHANISM SHOULD BE REMOVED

of this machine there are no external knobs or levers to operate, and the usual recording handle has been eliminated. The electric time control sets the mechanism and the operation is completed by the power unit.

Location of Recorders

The number of employees using a time recorder should be limited to 100; there should, however, be a recorder for each shop, even though the number of employees in the shop may be small. The ideal position for the location of the recorder is inside the shop near to the exit. If it is a large shop requiring several recorders this may not always be convenient, but in all cases it is particularly desirable that the recorder should be placed in such a position as will give the maximum circulating area; if not, congestion is bound to occur. At each side of the time recorder a rack should be fitted capable of holding 100 time or clock cards, and permitting of each operator's clock number being seen. The suggested arrangement is shown in Fig. 170. One rack should be clearly labelled "IN" and the other "OUT."

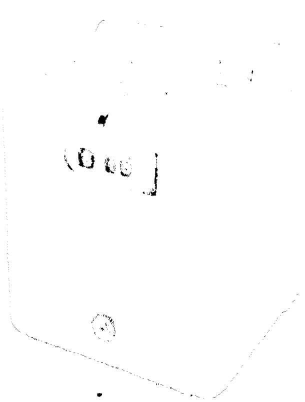


FIG 169 MOTORIZED TIME RECORDER WITH "DIRECT READ" TIME INDICATION

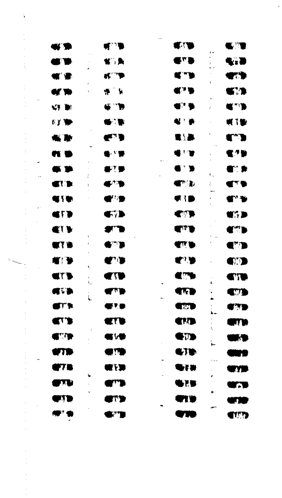
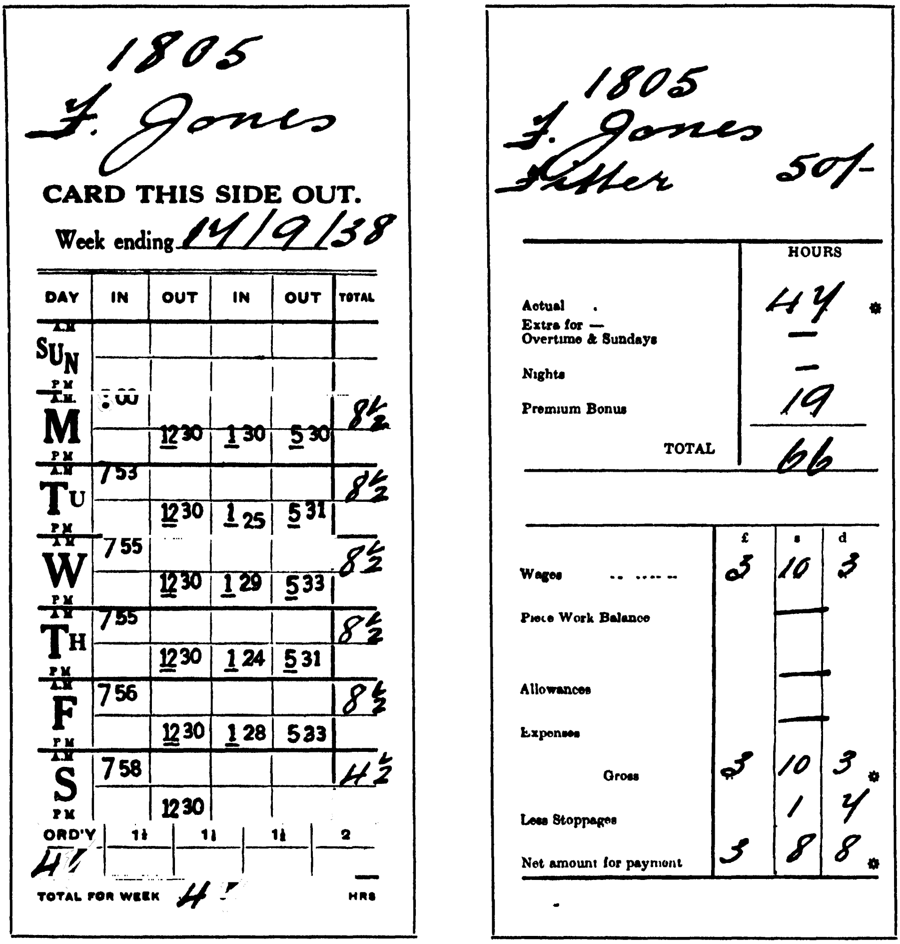


FIG 170 TYPE OF CARD RACK REQUIRED ON EACH SIDE OF RECORDER

Time Cards

The time or clock card should give a record of all arrivals and departures of an employee for an entire week. It is desirable that the ordinary time should be shown in blue ink, and late arrivals, early departures, and overtime shown in red ink. It is recommended that the time card should be printed on both sides. On the one side it should be suitably spaced for the actual clockings, and on the reverse side it should have information printed which will enable the employee to see in due course the make-up of his wages. A suitable card will measure approximately 7 in. × 3 in. and, when completed, will be similar to the

example illustrated, Fig. 171. If an employee is paid during the current week for work done during the previous week it is suggested that he should be given his previous week's card, showing his earnings, shortly before he is due to receive his wages, and should hand in this card as a receipt.



(*front*) (*back*)

FIG 171 TIME RECORDING CARD

(Suitable for either the Premium Bonus or Piecework System)

Clocking Irregularities

Weekly returns are necessary in order to clear up any type of irregularity, and these returns should be entered up twice daily by the clerical staff in each shop. The type of form recommended is illustrated in Fig. 172. As will be seen, the column headed "To be Paid From or To" is required

to be filled in by the personnel department.

Lost Time Books

Each shop should maintain a lost time book, in which the names of every employee are entered in alphabetical order. Each day of the week should be shown, and if the width of a double page is 18 in., one double page can cover a period of thirteen weeks, this arrangement being helpful in computing time lost in connection with any liability under the Workmen's Compensation Act. It is recommended that the following code be used—

1. Entries in black ink—illness.
2. Entries in blue ink absence with leave.
3. Entries in red ink—absence without leave.

A reproduction of the lost time book is given in Fig. 173.

Time Recording Instructions

In connection with time recording it is important that standard instructions should be drawn up for all concerned, and the following will form a suitable basis for such instructions -

Time Recording Instructions for Employees

(1) When an employee comes on

CLOCKING IRREGULARITY RETURN

Clock No Shop Week Ending 19

Clock Card No	Name	Day	Time of Omission to Record		Time of Late Recording In, or Early Recording Out	Mixed Clockings at	* To Be Paid From or To	Remarks
			In	Out				

* This column will be entered by the Personnel Department.

Fig 172 Clocking Irregularity Return

SHOP No

Clock No	NAME	Week Ending						Week Ending						Week Ending						Week Ending						Week Ending						Week Ending					
		M	T	W	T	F	S	M	T	W	T	F	S	M	T	W	T	F	S	M	T	W	T	F	S	M	T	W	T	F	S	M	T	W	T	F	S

Fig 173 Lost Time Book

duty he must take the card bearing his name and number from the rack marked "Out," and after placing the card in the slide provided for the clock and recording the time on his card, he must place the card in the rack marked "In." When an employee finishes duty the card must be taken from the rack marked "In" and, after recording, must be placed in the rack marked "Out."

(2) No employee is permitted to carry a clock card about with him; it must always be left in the appropriate rack.

(3) Unless authorized to do otherwise, each employee must record his time on his allotted recorder.

(4) No employee may record anyone's time but his own, and in no circumstances may clock records be altered or erased from the card.

(5) Employees must record "Out" within ten minutes after each stoppage, and must not record "In" earlier than ten minutes before the appointed time for commencing work.

(6) In consideration of the employees having to record their time "Out" at every stoppage of work, two minutes' grace will be allowed on each occasion of recording "In."

(7) The actual clocking off must not commence until the recognized official hours by clock time.

(8) Men leaving work for meals at other times than those appointed for this purpose must record "Out" when they leave the works, i.e. an employee working through the shop dinner hour and going out, say, from 1.30 p.m. to 2.30 p.m. must clock "Out" at 1.30 p.m. and "In" at 2.30 p.m.

Time Recording Instructions for Shop Clerks

(1) At the end of each week, completed clock cards must be collected and new ones placed in the racks in readiness for the next week.

(2) No alterations or initials are to be made on clock cards.

(3) All omissions to record, late or early clockings, or other irregularities, must be entered on the irregularity returns. This should be done each morning and afternoon by the time clerk visiting the recorder.

(4) All lost time must be correctly recorded each day in the lost time book.

(5) The foreman's attention must be called to all cases of erasure, or other tampering with clock cards by employees.

(6) For the purpose of drawing wages the clock cards of the preceding week, which will show the make-up and amount of wages due, must be issued to the staff each pay-day to be given up again at the pay station in exchange for the pay packets.

(7) Irregular clockings will be corrected and initialed by the personnel department, and the irregularity returns completed by entering the times to be paid from, or to, in the case of late or early clockings.

(8) A record of omissions to clock will be kept by the personnel department, and in the event of an employee omitting twice within four weeks, disciplinary action will be taken.

Time Recording Instructions for Personnel Department

(1) All cases of omissions to clock to be entered on the irregularity

returns. Employees omitting twice within four weeks to be suitably reprimanded.

(2) In dealing with late clockings (assuming that the normal day shift is 8 a.m. to 12.30 p.m. and 1.30 p.m. to 5.30 p.m. and that two minutes' grace is allowed on each occasion of recording in at the official starting times) the following ruling will apply—

Employees clocking in late between—	*To be paid from—*
8.3 a.m. and 8.15 a.m. inclusive . . .	8.15 a.m.
After 8.15 a.m. (if allowed to start) . . .	Next ¼ hour
1.33 p.m. and 1.45 p.m. inclusive . . .	1.45 p.m.
After 1.45 p.m. (if allowed to start) . . .	Next ¼ hour

All instances of late clockings to be entered on the irregularity return.

(3) *Employees clocking before time.* At 12.30 p.m. and 5.30 p.m. pay to be made to the previous quarter of the hour when employees clock out two minutes before time, and all these cases to be entered on the irregularity return.

Attention to be called to employees who persistently clock out one minute before time and, when on overtime duty, pay to be made to the previous quarter of the hour, e.g. employees clocking out at 7.29 p.m. when working overtime to be paid to 7.15 p.m.

Employees leaving duty early, with permission, must record "Out" at a level quarter-hour, e.g. 12 noon or 5.15 p.m., etc.

(4) *Employees booked on Sunday duty but recording in late after* 8 *a.m.* Pay to the next quarter of the hour, e.g. employees clocking in at 8.1 a.m. pay from 8.15 a.m. (no grace allowance).

(5) *Erasures.* Attention to be called to any attempt to erase a clocking.

(6) *Irregular meal hours.* Employees taking early or late dinner or supper hours, for the firm's convenience, must record at a level quarter-hour.

Advantages of Time Recording

The advantages to be obtained by the adoption of the system outlined may be briefly stated as follows—

1. *In the Works.* By visiting the clocks twice daily and entering omissions, late clockings, and other discrepancies on the irregularity returns the shop clerks will be able to—

(*a*) advise the foremen of the number of men off duty;

(*b*) prevent employees from duplicating a clocking, e.g. if the cards were not checked daily, an employee coming in late at, say, 8.3 a.m. on Monday could omit to clock, and on Tuesday stamp a double clocking at 8 a.m., thus claiming one of these clockings for Monday on the pretence tnat the card on Monday jammed in the card chute, in which circumstances there may be no proof to the contrary;

(*c*) have the cards ready for release by 9 a.m. on Mondays, whereas if all the checking were left until the end of the working week the cards would be considerably delayed, particularly before holiday periods.

2. *In the Personnel Department*

(*a*) Concentration of check on time recording is achieved.

(*b*) To ensure a standard and correct payment, the times to be paid "to or from" for omissions and late and early

clockings are entered on the irregularity returns by the personnel department staff, after checking with any reports of clock defects which are received from the clock mechanic. The settlement of disputes will rest with the head of the department.

(*c*) Employees who persistently record late are reported to their foreman.

(*d*) Only the initials of authorized staff in the personnel department are accepted on clock cards, false entries thus being prevented.

(*e*) Omissions are recorded, and disciplinary action regulated. If a penalty were not imposed an employee coming in late could decide not to record, and be paid full time, claiming that he only omitted to record.

(*f*) Attention is called to any clocking defects so that the clock mechanic may be instructed to adjust the recorder.

(*g*) A definite control over all time recording is maintained.

(*h*) A register can be kept showing the total number of irregularities each week and the average for the year (Fig. 174).

3. *In the Wages Office.* Cards will be available early on Monday and there will be no question of the wages office staff having to refer cases to the personnel department for settlement, because all the necessary checking has

CLOCKING IRREGULARITIES
YEAR 1940

Week Ending	Omissions to Clock	Late Clockings	Early Clockings	Total	Remarks
January 6th	7	78	38	123	Buses delayed due to frosty weather
January 13th	6	36	14	56	
January 20th	10	18	8	36	
January 27th	8	59	16	83	
February 3rd	5	45	12	62	
February 10th	12	138	89	239	Heavy fall of snow
February 17th	6	37	22	65	
February 24th	14	124	65	203	Trams late due to foggy weather
March 2nd	5	41	23	69	
March 9th	19	52	18	89	
March 16th	6	44	19	69	
March 23rd	4	12	7	23	Easter Holidays
Average Weekly	11	60	28	99	Slight improvement on previous year

FIG. 174. REGISTER OF CLOCKING IRREGULARITIES

been done by the latter, who are responsible for the supervision of time recording. The fact that employees will be aware that late clockings are recorded on the irregularity returns will have a retarding effect on late clockings generally.

Time Signals

Machines are available which will control any equipment which can be

FIG. 175. PORTABLE TIME DETECTOR

operated by an electric relay and which has to be switched on or off to a prearranged time schedule. These machines are so arranged that selection can be made of any minute throughout the week. Such machines are not restricted to one function, as different pieces of apparatus can be connected to the one cabinet, each having a different time schedule from the other. They are particularly suitable for sounding bells, works' hooters, and similar signals, and also for governing light switches.

Fireman's Portable Time Detector

For firemen and watchmen who are covering a definite patrol it is essential that they should carry with them a time detector (Fig. 175), thus ensuring that they are making their patrol in a thoroughly satisfactory manner. At the various points to which it is desired visits should be made during day or night, special numbered keys are fixed on chains. The fireman carries the detector in a stout leather pouch with shoulder strap. On reaching each point he inserts and turns the key in the detector, each key being of a different pattern. This operation prints the number of the station and the time at which the key was turned in plain figures on a continuous roll of paper (Fig. 176) inside the detector. In this way a complete record of the patrol of the fireman is secured in a convenient and legible form.

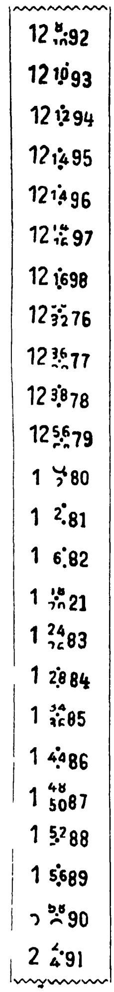


FIG 176 FACSIMILE OF PORTABLE TIME DETECTOR RECORDING PAPER

Maintenance of Time Recording Equipment

A record of all time recorders and similar equipment, giving distinctive number, date purchased, make, type, cost, where located, and any other relevant particulars, will prove helpful.

Many large firms will find it the more

convenient arrangement to employ their own full-time clock mechanic. Others may prefer to place a contract with the manufacturer for the periodical inspection and maintenance of clocks and time recorders.

Time flies, but method catches it.

GOETHE.

CHAPTER XV

WORKSHOP EXPENSES

Meaning of Term

THE term "workshop expenses" may need some explanation. It includes all shop charges which are incurred in the provision of services, labour, material, and equipment necessary to operate a factory, and which are not chargeable directly to a manufacturing account. Workshop expenses are frequently referred to as production oncosts or overhead expenses.

The control of the multifarious activities which fall under the broad heading of workshop expenses is a task which requires the utmost vigilance on the part of every member of the managerial and supervisory staff. Adequate attention to this section of factory expenditure is the essence of good management. The acid test as to whether any factory expense is justified is to ask the simple question, before the money has been spent, "Would you consider it to be good value for your money if you had to pay for it out of your own pocket?" It is suggested that if this question was invariably put to the individual authorizing the expenditure, there would often be a substantial saving.

Coding of Workshop Expenses

The best plan is to give each section of workshop expenses a distinctive number or code number called a factory order number, which may be identified by the abbreviation W.E. or F.O. For example, W.E.5 inserted on a stores requisition for material, or on a wages document, will imply that the expenditure is chargeable to workshop expenses on Factory Order No. 5. The identification can be made still more complete by quoting the office or shop concerned, e.g. W.E.5/12 will mean that the particular charge is debitable to Shop No. 12, or, if desired, the shop number and the factory order number can be transposed, e.g. W.E.12/5.

Sometimes subdivisions of a factory order are desirable. A good example to consider is that of the inter-shop transport where it is advisable to ascertain the particular sources of expense. Five sections suggest themselves as follows—

Reference Letter	*Section*
A	Maintenance (Mechanical and Electrical)
B	Oil and Grease
C	Petrol (or Batteries)
D	Trailers
E	Tyres

Assuming the factory order for the trucks and tractors to be W.E.36, then W.E.36/C/6 would refer to a supply of petrol chargeable to motor No. 6. The actual quantity would be mentioned in the appropriate column. If, as is recommended in Chapter XVII, the shop transport is under centralized control, the cost will be a general charge on the works.

Variable and Non-variable Expenses

Workshop expenses are of two kinds, variable and non-variable. From the list overleaf (Table XV) which is representative of the average engineering factory, it will be seen under which headings various items of expenditure may be classified. It will be appreciated that there is a point beyond which a subdivision cannot be conveniently taken.

As will be realized, certain of these expenses are applicable to the works as a whole. In these cases the outlay is regarded as a general expense, and the total amount involved is charged to the different shops in proportion to the direct wages of each shop, unless specifically desired otherwise.

From the point of view of departmental responsibility of the various works assistants, it is sometimes preferred to group the various workshop expenses according to the services controlled, such as the building, power, tool, and stores services, or shop administration service. In Table XV foremen, assistant foremen, examiners, finished work inspectors, rate-fixers, shop clerks, and all stationery incidental thereto come within the latter category, the classification of all these being non-variable.

In certain special circumstances, as for instance when a portion of a factory is being closed down, items shown as variable may become non-variable and vice versa. The division of workshop expenses under these two headings then becomes all-important because anticipated savings are involved, but in other circumstances this division is comparatively unimportant.

Correct Allocation of Charges

It is strongly recommended that work which is quite dissimilar in character, even though it may be carried out in the same department or under the same roof, should have separate workshop expenses accounts in view of the wide difference in percentage applicable, e.g. in the case of a foundry there should be four sections, under the headings of (1) core-making, (2) melting and casting, (3) moulding, and (4) fettling. This can be achieved without much difficulty.

In those instances where equipment or indirect labour is required for a dual purpose a predetermined percentage figure, open for revision at any time, should be supplied to the costs accountant for a fair allocation of any charges. For example, assume that the rate-fixing required for a shop involves one rate-fixer. Then if it is considered that on an average he spends two-thirds of his time in connection with what we will describe as Section A of the shop, and the remaining third in connection with Section B, then 67 per cent of the rate-fixing cost would require to be debited to Section A and the remaining 33 per cent to Section B.

Let us take an actual case which has occurred in practice. Experiment revealed that three oil-fired furnaces (A), (B), and (C), used jointly for normalizing and case-hardening, burnt two gallons of oil per hour at a temperature of 850° C., and one oil-fired furnace (D), used for annealing copper pipes, burnt $1\frac{1}{2}$ gallons of oil per hour at a temperature of 700° C. Furnaces (A), (B), and (C) were in use for 16 hours a day, 5 days per week, and

TABLE XV

CLASSIFICATION OF WORKSHOP EXPENSES

Factory Order No.	Item of Expenditure	Class of Expense
W.E.1	Accessories and Tools	Variable
W.E.2	Accidents	Non-variable
W.E.3	Acetylene Generating Plant	Variable
W.E.4	Air Compressors	Variable
W.E.5	Ambulance Materials	Non-variable
W.E.6	Attendants	Non-variable
W.E.7	Boilers and Stationary Engines	Variable
W.E.8	Cleaning and Lubricating Oil, and Labour	Variable
W.E.9	Clothing and Uniform	Non-variable
W.E.10	Coal, Coal Dust, Coke, Sand, Limestone, etc.	Variable
W.E.11	Cranes	Variable
W.E.12	Cupolas, Crucibles, and Furnaces	Variable
W.E.13	Cutting Compounds and Small Stores Items	Variable
W.E.14	Defective Work	Variable
W.E.15	Detachable Fittings—Gas, Water, and Electric	Non-variable
W.E.16	Dining and Mess Rooms	Non-variable
W.E.17	Electric Motors, including Switches and Wiring	Variable
W.E.18	Electric Trucks	Variable
W.E.19	Electricity, including Lamps	Variable
W.E.20	Examiners, Finished Work Inspectors, and Rate-fixers	Non-variable
W.E.21	Experimental Work	Non-variable
W.E.22	Foremen and Assistant Foremen	Non-variable
W.E.23	Fuel Oil	Variable
W.E.24	Gas for Acetylene Welding Plant	Variable
W.E.25	Gas, including Mantles and Fittings	Non-variable
W.E.26	Gatemen and Watchmen	Non-variable
W.E.27	Hand Carts and Wheelbarrows	Variable
W.E.28	Hand Tools and Brushes	Variable
W.E.29	Heating and Ventilating Apparatus	Non-variable
W.E.30	Hydraulic Accumulators, Presses, and Pumps	Variable
W.E.31	Jigs, Fixtures, and Templets	Variable
W.E.32	Machine Repairs, Fixed and Portable	Variable
W.E.33	Mains	Variable
W.E.34	Materials for Test Purposes	Non-variable
W.E.35	Pattern-making, where not charged to Manufacturing Account	Non-variable
W.E.36	Petrol Trucks, Tractors, and Road Motors	Variable
W.E.37	Piping, and Tanks for Fuel Oil	Non-variable
W.E.38	Provision for Plant and Machinery	Variable
W.E.39	Pulleys, Shafting, and Bearings	Variable
W.E.40	Shop Clerks	Non-variable
W.E.41	Shop Equipment, including Benches, Cupboards, Racks, etc.	Non-variable
W.E.42	Shop Office Equipment and Fittings	Non-variable
W.E.43	Shop Storesmen	Non-variable
W.E.44	Shop Transport	Non-variable
W.E.45	Stationary Enginemen and Furnacemen	Non-variable
W.E.46	Steam and Pneumatic Hammers	Variable
W.E.47	Time Recording Clocks and Apparatus	Non-variable
W.E.48	Water, including Pressure Water	Variable
W.E.49	Yard Labourers	Non-variable
W.E.50	Yard Shunting, including Working Costs	Non-variable

therefore had a weekly consumption of 480 gallons of fuel oil. These furnaces were, however, used for normalizing forgings for two-sevenths of their time, and consumed for this purpose approximately 140 gallons of oil per week. The annealing furnace (D) was in use for 8 hours a day, 5 days per week, and therefore had a weekly consumption of 60 gallons of fuel oil.

Accordingly, the allocation of fuel oil charges should be—

Normalizing account
= $\frac{2}{7}$ (A), (B), and (C) = $\frac{2}{7}$ × 480 gal.
= 137 gal. = say, 25 per cent.

Case-hardening account
= $\frac{5}{7}$ (A), (B), and (C) = $\frac{5}{7}$ × 480 gal.
= 343 gal. = say, 65 per cent.

Annealing account
= (D) = 60 gal. = say, 10 per cent.

In the same shop a stationary boiler, Registered No. 6, was used jointly for steam heating the shop as well as for atomizing the fuel oil supplied to the four furnaces (A), (B), (C), and (D). It was estimated that 80 per cent of the steam was supplied to the shop, and the remaining 20 per cent to the furnaces, this latter amount to be divided according to the fuel oil consumption as given.

In the case therefore of the boiler, the "Provision for Plant and Machinery" and the "Repairs to the Boiler" were each divided as follows

Shop . .	80%
Normalizing .	5% (i.e. 25% of 20%)
Case-hardening .	13% (i.e. 65% of 20%)
Annealing .	2% (i.e. 10% of 20%)
	100%

A statement should be drawn up quoting all such items and a copy of this statement should be supplied to the costs accountant to enable him to apportion the charges correctly. It is, of course, desirable that such information should be kept up to date, as changes will inevitably occur from time to time.

Method of Expressing Workshop Expenses

It is customary to express the total workshop expenses of a shop as a percentage of the productive or direct wages figure payable in that shop. In short, if the direct wages of a certain shop amount to £1000 over a period of four weeks, and during that same period the workshop expenses, both variable and non-variable, amount to £750, then it is said that the workshop expenses of the shop are 75 per cent. This figure might be made up, say, of 30 per cent variable and 45 per cent non-variable expenses. Unless there is a special reason for doing otherwise, workshop expenses should normally be based on the figures obtained during the past 12 months (i.e. the most recent 13 four-weekly periods). This avoids sudden changes.

There are some administrators who advocate that workshop expenses be applied strictly on a time basis, that is to say, according to the actual length of time each productive operation has taken. Whilst it may appear to be the more logical method, it has its drawbacks and is certainly not recommended by the author in view of the extra clerical labour involved. Particularly does this observation apply where a piecework system is in operation.

As one might reasonably expect, the amount of workshop expenses varies. Much depends on the class of work. Where the equipment used is expensive and the direct wages are comparatively small, they will appear to be very excessive and probably as much as 250 per cent. It does not follow that the shop is working uneconomically, especially if the piece-work prices paid per article are keen. Nor does it necessarily follow, because in one shop a certain item of workshop expense is found to work out at 6d. per man per week and in another shop at only 2d. per man per week, that the former is uneconomical. The class of work carried out largely enters into such a comparison.

WAGES AND WORKSHOP EXPENSES RETURN FOR

Shop	No of Wages Staff		Hours Paid For				Wages		Lodging and Travelling Expenses	Total as per Pay Bill of (G+H+J)
	On Books	At Work	Man Hours Actually Worked	Added for Overtime Day Shifts	Added for Night Shifts	Total of (C+D+E)	Directly Appropriated	Own Shop Expenses		
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(J)	(K)
							£	£	£	£
Assembly	160	156	30,330	1,201	212	31,743	2,000	207	18	2,225
Machine	534	518	87,950	43	4,404	92,397	5,480	1,265		6,745
Aggregate	694	674	118,280	1,244	4,616	124,140	7,480	1,472	18	8,970

FIG. 177 FOUR WEEKLY WAGES
(Covering all Shops and

Direct Charges

There are, of course, many occasions when comparatively expensive tools or other equipment are required to be specially made in order that a contract may be undertaken. In these cases it is recommended that the entire cost should be debited to the outside order, in which event there will be no actual charge on workshop expenses for the items concerned. Where there is a possibility of further orders of an identical character being received, some discretion will need to be exercised as to whether or not only a portion of the new equipment required shall be debited to the initial manufacturing order. Each of these special cases will require to be considered on its merits, such items as jigs, templets, gauges, flanging blocks, dies and die blocks, patterns, and special tools all being involved. Whatever decision is given, it should be made effective by the central planning office referred to in Chapter XXII, from which the documents will be issued with the charges correctly apportioned.

So far as machine tools and other fixed equipment are concerned, the amount to be debited to workshop expenses each four-weekly period will be based on the capital value of each individual item. For this purpose the record card shown in Fig. 88 (Chapter VII) should be used.

a four-weekly foundry cost account, Fig. 179.

Those items which represent the major portion of the workshop expenses for a particular shop should be plotted separately for every period in terms of pence per man, thus enabling the position to be closely watched. If

FOUR WEEKS ENDING 28TH JANUARY, 1940

Average Wages Earned per Actual Hour Worked $\frac{K}{C}$	Average Weekly Earnings per Man at Work $\frac{K}{4B}$	Approximate Cost of Overtime and Night Duty in excess of Ordinary Pay	Workshop Expenses and Percentages on Directly Appropriated Wages: Supervision	$\frac{O}{G}$	Registered Plant and Machinery	$\frac{Q}{G}$	Other Expenses	$\frac{S}{G}$	General	$\frac{U}{G}$	Total: O + Q + S + U	$\frac{W}{G}$	Average of Y% 13 Periods
(L)	(M)	(N)	(O)	(P)	(Q)	(R)	(S)	(T)	(U)	(V)	(W)	(Y)	(Z)
s. d.	£ s. d.	£	£	%	£	%	£	%	£	%	£	%	
1 5·60	3 11 4	82	106	5·3	66	3·3	255	12·8	241	12·1	668	33·4	35·3
1 6·41	3 5 1	259	265	4·8	2,136	39·0	1,354	24·7	764	13·9	4,519	82·5	86·9
1 6·20	3 6 6	341	371	5·0	2,202	29·4	1,609	21·5	1,005	13·4	5,187	69·3	65·0

AND WORKSHOP EXPENSES RETURN

giving Works aggregate)

Statistics

A wages and workshop expenses return to cover all shops should be drawn up by the costs accountant every four-weekly period on the lines indicated in Fig. 177. It is self-explanatory, and should be carefully studied as it will have tremendous practical value.

Another return called the "wages and workshop expenses individual shop return," which is illustrated in Fig. 178, should also be prepared and sent to each foreman concerned. In the case of the foundry this return should be supplemented by

these graphs are prepared on squared paper of foolscap or other convenient size, they can be placed in separate folders for each shop and sent to the head of the particular department concerned, together with his copy of the workshop expenses and individual shop return, asking for his comments on any item specially marked due to a noticeable increase. The type of graph suggested is illustrated in Fig. 180, and, where the user warrants it, the graph paper should be specially printed to avoid any unnecessary lines. It will be observed that the suggested graph covers a period of two years.

AERO Department

WAGES AND WORKSHOP EXPENSES RETURN

PATTERN

Four Weeks to 28*th January* 1940 Shop No 8

Average No of Staff		Hours Paid for					Wages		Total as per Pay Bill	Average Wages Earned per Actual Hour Worked	Average Weekly Earnings per Man at Work
On Books	At Work	Man Hours Actually Worked	Added for Overtime	Added for Nights	Bonus	TOTAL	Directly Appropriated	Own Shop Expenses			
28	27	5076	18	—	2037	7131	£325	£75	£400	1s 6 9d	£3 7

WORKSHOP EXPENSES

	Supervision	Plant and Machinery	Workshop Expenses	General	Total
	£ s d	£ s d	£ s d	£ s d	£ s d
Salaries—Own Shop	30 0 0				30 0 0
Wages Do				75 0 0	75 0 0
Do Other Shops		15 0 0	7 10 0		22 10 0
Materials		2 15 0		8 0 0	10 15 0
Gas, Water, and Electricity				2 15 0	2 15 0
Share of Stores, Yards etc				30 0 0	30 0 0
Renewal Fund		12 0 0			12 0 0
Total	30 0 0	29 15 0	7 10 0	115 15 0	183 0 0
Percentage on Total Wages	7 5	7 4	1 9	28 9	45 7

DETAILS OF PRINCIPAL ITEMS OF MATERIAL

No or Qty	Description	£	No or Qty	Description	£
	General —				
	Gas	1			
	Electricity	1¾			
	Miscellaneous				
	Emery Cloth	¼			
	Cabinet Makers Glue	¼			
3 doz	Sponge Cloths	⅛			
1 pair	Cutters for Wadkin Milling Machine	1¼			

FIG 178 WAGES AND WORKSHOP EXPENSES INDIVIDUAL SHOP RETURN

In addition, it will often prove to be time well spent to prepare a six-monthly statement from the four-weekly returns previously referred to, showing those items which are common to most shops and which have a attachments for machines, etc., in use. Eight main classifications are recommended, and under each classification the items should be arranged in alphabetical order and each shop recorded separately.

FOUNDRY COST ACCOUNT

FOUR WEEKS ENDING 28TH JANUARY, 1940

EFFICIENCY FACTORS

ALLOY	INPUT			OUTPUT				Cost per cwt. Rough Castings including Melting and Casting Expenses
	New	Reno-vated	Scrap	Castings Net Weight	Gits and Runners	Shop Scrap	Loss in Melting	
	%	%	%	%	%	%	%	£ s. d.
B1 . .	0·31	33·96	65·73	83·13	13·72	0·15	3·00	2 10 7
B2 . .	5·44	7·63	86·93	88·91	7·72	0·67	2·70	2 17 1
Aluminium.	8·95	—	91·05	79·86	18·84		1·30	1 10 4
Duralumin	54·62	—	45·38	80·33	18·90		0·77	4 9 2

Materials Used	Per ton of Input	Per ton of Net Output
Melting and Casting—		
Fuel Oil . .	27 gal.	
Coke . . .	78 lb.	
Moulding—		
Sand . . .		349 lb.
Core-making—		
Sand . . .		299 lb.

FIG. 179. FOUR-WEEKLY FOUNDRY COST ACCOUNT

high user. Such a statement is shown in Fig. 181.

Inventory of Plant

The intelligent control of workshop expenses provides many opportunities for keeping invaluable records concerning the plant.

As a case in point, a check will need to be taken from time to time, for stocktaking and other purposes, of all small tools, gauges, accessories, and

It is recommended that these be compiled as shown in Fig. 183. The prices shown will be consistent with current trade prices. A summary sheet, Fig. 182, will give the total value of unregistered equipment for the works. In Fig. 182 the vertical totals will give the monetary value of individual sections, and the horizontal totals the monetary value of all the sections in each shop, thus providing a most informative statement.

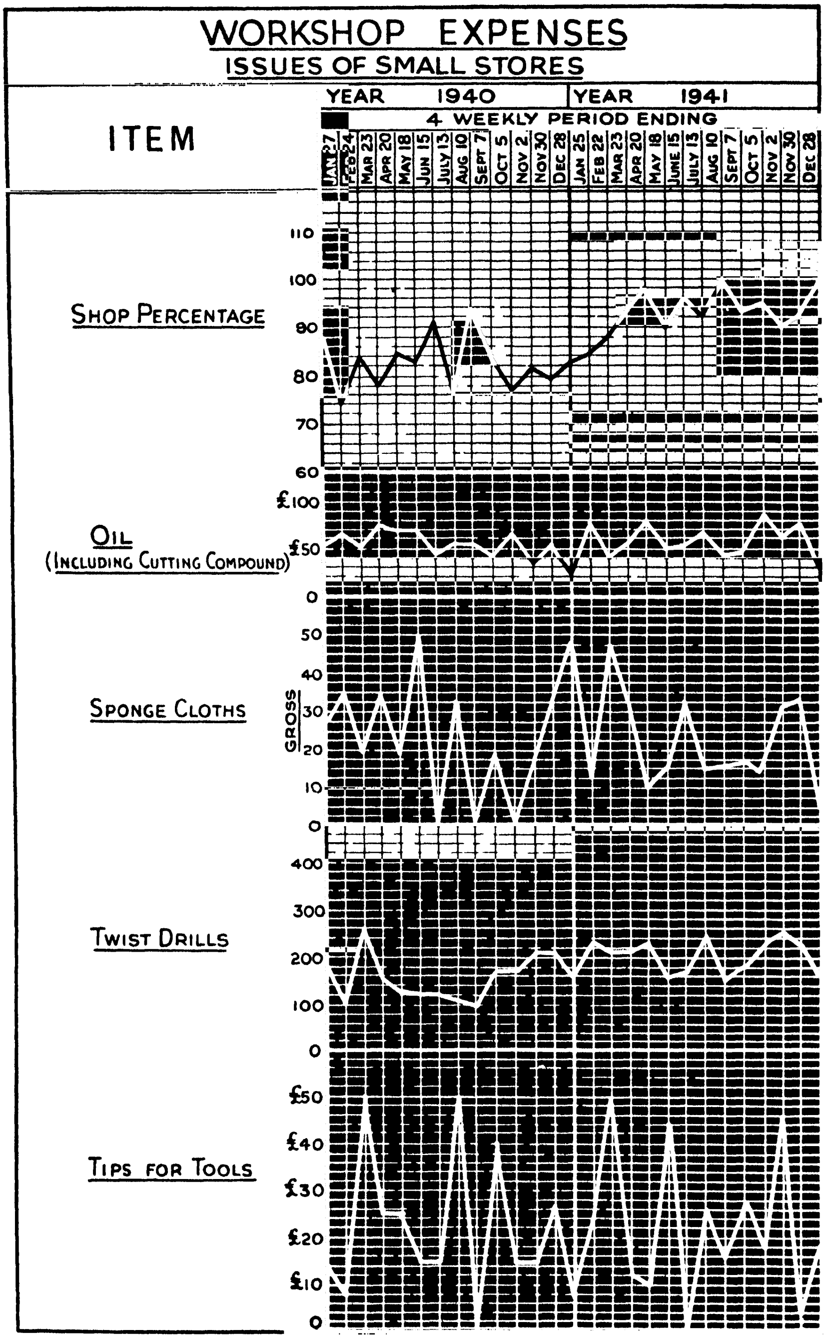


FIG 180 GRAPHS DEPICTING PRINCIPAL ITEMS OF WORKSHOP EXPENDITURE (INDIVIDUAL SHOP)

STATEMENT SHOWING EXPENDITURE INCURRED IN SELECTED ITEMS OF WORKSHOP EXPENSES

COMPARISON BETWEEN SIX MONTHS ENDING 30TH JUNE 1940 AND SIX MONTHS ENDING 30TH JUNE 1941

Shop		Average No. of Men Employed during Period		Cost in Terms of Pence per Man Employed															
				Abrasive Wheels		Brushes		Cleaning and Lubricating Oil		Defective Work		Emery Cloth and Sand-paper		Files		Soap		Sponge Cloths	
No.	Description	1940	1941	1940	1941	1940	1941	1940	1941	1940	1941	1940	1941	1940	1941	1940	1941	1940	1941
1	Brass Foundry	75	81	9·2	8·9	3·7	5·9	5·9	5·3	27·8	24·7	4·6	3·9	4·9	4·1	2·0	2·5	4·6	4·1
2	Coppersmiths'	53	51	2·2	2·1	1·1	1·1	1·7	1·8	—	—	2·7	2·1	18·2	17·4	7·5	6·4	6·4	4·3
3	Fitting .	320	338	0·7	0·9	4·8	5·2	0·3	0·4	2·2	2·3	3·1	4·7	47·2	50·2	1·5	1·7	5·5	6·2
4	Forge . .	58	50	—	—	1·2	1·4	8·8	7·3	4·3	3·1	1·4	1·3	12·4	10·0	4·3	5·2	4·0	3·1
5	Iron Foundry	42	38	12·1	11·0	7·2	7·5	8·4	8·0	30·8	26·0	7·4	7·7	3·4	2·3	2·1	2·7	4·6	4·6
6	Machine . .	596	677	17·3	19·1	4·0	3·6	7·8	6·2	4·2	2·2	4·6	5·0	—	—	1·3	1·2	8·0	8·3
7	Machine (Heavy)	141	149	10·6	12·4	4·6	3·9	10·3	12·0	6·2	6·0	9·1	9·5	—	—	1·9	1·7	8·1	8·2
8	Pattern .	28	24	—	—	1·3	1·2	1·0	1·1	—	—	8·1	6·4	1·1	1·0	1·2	1·3	3·1	4·1
9	Welding	8	10	3·2	3·7	1·0	1·1	0·5	0·7	0·2	0·5	1·8	2·1	2·6	2·9	1·9	2·0	3·3	3·9

FIG. 181. COMPARISON BETWEEN SHOPS OF ITEMS HAVING A HIGH USER

INVENTORY OF SMALL TOOLS AND UNREGISTERED EQUIPMENT

Shop	*Class 1* Accessories and Attachments for Machines	*Class 2* Gauges	*Class 3* Jigs, Templets and Fixtures	*Class 4* Lifting Tackle	*Class 5* Patterns, Core boxes and Moulding Boxes	*Class 6* Pneumatic and Hydraulic Tools	*Class 7* Shop Fittings and Equipment	*Class 8* Small Tools and Hand Tools	Total
	£	£	£	£	£	£	£	£	£
Coppersmiths'	45	28	242	35	Nil	Nil	525	380	1,255
Foundry .	74	36	24	385	240	Nil	496	7,640	8,895
Pattern	144	56	Nil	6	25,400	Nil	886	238	26,730
Forge	2,038	64	270	126	Nil	Nil	372	784	3,654
Machine	16,580	1,820	11,340	475	Nil	88	3,870	8,632	42,805
Assembly	2,680	462	5,475	686	Nil	212	2,684	10,498	22,697
TOTAL . .	21,561	2,466	17,351	1,713	25,640	300	8,833	28,172	106,036

FIG. 182. VALUE OF UNREGISTERED EQUIPMENT

Superintendence

There are many engineers who confuse workshop expenses with superintendence. Actually these terms have distinctly different meanings. They are only similar inasmuch as the expenditure under each is expressed as a percentage of the direct wages, but even in this respect there is a difference. It has been shown that with workshop expenses the percentage applied varies in each shop—sometimes on different sections of work within the shop—but with superintendence, which has no particular association with any department or shop, and is a general charge throughout the factory, only one percentage is applicable. This is calculated by expressing the actual expenditure incurred under superintendence as a percentage of the whole of the direct wages for the factory. In round figures this should not exceed 10 per cent. The cost of the entire administration will be chargeable to superintendence and will include such departments as those of the works manager (embracing, for instance, the planning, estimating, and progressing sections), design, personnel, stores, accountants, research, advertising, and sales.

In some instances "Superintendence" is confined to those sections of office personnel coming under the jurisdiction of the works manager. Where this is done the expenses of the other administrative sections of the concern need to be put under a separate heading of "General Charges." It will be appreciated that the net result is the same.

SMALL TOOLS INVENTORY FORM

CLASS 1. ACCESSORIES AND ATTACHMENTS FOR MACHINES

MACHINE SHOP

Description of Article	Qty.	Dimensions	Price Each	Total Amount	Remarks
				£ *s.* *d.*	
Abrasive Discs	600	Various	2s. 3d.	67 10 0	Mostly new
Abrasive Bands for Do	26	Do	8d.	17 4	
Boring Bars	278	1 in to 4 in dia.	£5 (Av)	1390 0 0	"Nulock" pattern
Boring Bits	120	9 in. long × 1 in shank	3s.	18 0 0	
Broaches	8	1¼ in. × 1 ft. 8 in	£4	32 0 0	Nickel Steel

FIG 183 INVENTORY OF SMALL TOOLS

CHAPTER XVI

ELIMINATION OF WASTE

Classification of Waste

WASTE in industry may take many forms, both tangible and intangible, and may be considered to come within four groups—

(1) Low production.

(2) Intermittent production.

(3) Restricted production.

(4) Lost production.

In Group 1 there are six principal causes of waste, as follows

(*a*) Faulty material control—due to inefficient speculative purchase and lack of organized central planning.

(*b*) Faulty design control—due to absence of standardization, involving new tool layouts, and changing of design after the issue of the initial drawings.

(*c*) Faulty production control—due to lack of schedules and efficient progressing.

(*d*) Lack of cost control—accountancy requires investigation in order to provide reliable data, and to avoid any repetition of a previous mistake.

(*e*) Faulty control of personnel—results in inefficient workmanship, sometimes in unnecessary accuracy, and it sometimes takes the form of employing staff on unremunerative work. Furthermore, it is not uncommon for no one to have time to teach the less experienced personnel in accordance with any preconceived plan, each individual being expected to learn by observation rather than by specific instruction. This absence of organized instruction commonly lessens the chance of right selection of personnel for particular jobs and for new responsibilities and its effects may therefore be far-reaching.

(*f*) Faulty sales policies due to cancellations, poor credits, and disregard of seasonal fluctuations.

In Group 2 there are two causes, as follows

(*a*) Idle material—excessive buying resulting in obsolescence and depreciation.

(*b*) Idle plant and equipment—unbalanced production, due to there being no definite programme which co-ordinates materials, machines, and equipment.

In Group 3 there are also two causes—

(*a*) Management restricting factory output with the object of maintaining high prices.

(*b*) Restriction of individual output by employees, due to unemployment, to the inherent fear of piecework prices being reduced if high bonuses are earned, or to a desire to make room for more workers.

In Group 4 the principal causes are absences due to—

(*a*) Ill health.

(*b*) Defective vision.

(*c*) Industrial accidents and diseases.

Independent Investigations

There may come a time when it is advisable, with a view to the elimination of wasted time and materials, to carry out a close investigation into existing practices. It is an important duty which obviously requires the utmost tact if it is to be carried out efficiently, and the individual or individuals appointed should be intimately familiar with the organization but preferably should be independent of the department or departments investigated. The idea underlying such an investigation would be to increase the efficiency of the factory and also to assist each departmental head in his administrative duties. In some respects it is motion and time study (see Chapter XVIII) applied to the organization itself, rather than to the individual.

Each office and shop would require to be dealt with independently, and all concerned should be asked to give every assistance to the investigators. It should be understood that no recommendations or results of the inquiries should be intimated to the foremen and others by the investigators themselves.

Outline of Investigations

Whilst the following suggestions are not exhaustive, they will at least form a basis for an investigation on the lines indicated.

1. *Office Organization*

(*a*) To ascertain whether any records are maintained or whether work is carried out unnecessarily.

(*b*) To ascertain whether any new records could with advantage be put into operation, and if so to state exact requirements.

(*c*) To arrange for approved records common to all shops to be compiled on identical lines.

(*d*) To decide on a standard method of filing correspondence.

(*e*) To ascertain whether the number of outgoing telegrams and telephone calls is excessive, due to lack of systematic attention.

2. *Foremen and Assistant Foremen, Rate-fixers, Finished Work Inspectors, and Chargemen.* To ascertain duties and capabilities, also whether methods adopted are reasonably standard as well as the best possible. To state, further, whether it is considered any advantages would accrue by an internal changeover, i.e. a transfer from one section to another.

3. *Staff.* To consider to what degree and by whom the immediate control of the staff is exercised.

4. *Work Groups.* To consider the desirability of reorganizing any particular section or sections in respect of the class of work carried out.

5. *New Designs or Alterations to Existing Designs.* To fix method of dealing with shop drawings, and of putting authorized alterations into immediate operation.

6. *Printed Forms and Returns.* To review type, method of dealing with, and necessity for these forms.

7. *Internal Delays.* To consider organization for overcoming section to section delays. To investigate amount of illness, lost time, and machinery breakdowns.

8. *External Delays.* To fix methods

adopted for overcoming recurrent shop to shop delays.

9. *Experimental Work.* To fix the method to be adopted for expediting and for recording completion.

10. *System or Systems in Operation for Progressing Work.* To make recommendations for improvements.

11. *Shop Scheduling.* To consider the possibilities of instituting a schedule system for individual sections, by the introduction of suitable progress and schedule boards or charts in each shop.

12. *Shop Transport.* To consider existing arrangements for loading and unloading.

13. *Stores Department.* To consider arrangements for obtaining material from the stores.

14. *Recovery of Material.* To ascertain whether the best use is made of what is regarded as scrap material.

15. *Non-productive Staff.* To ensure that the non-productive staff is efficiently controlled, and to fix a maximum number of man hours for each grade.

16. *Defective Work.* To consider percentage losses, in both material and wages, due to defective work, and to take steps to improve the position.

Specific Analysis

To show the method which should be followed in carrying out the foregoing investigation it will be as well to consider in some detail the lines on which some of the inquiries should be followed.

Office Organization, Section 1 (*a*). The investigator should commence by tabulating every individual duty and separate function carried out in the particular office under investigation, and should ascertain from each member of the office the approximate time spent in hours over a four-weekly period on each duty performed. Having done this, the investigator should proceed to total the time spent in the office on each specific function, and to satisfy himself that it has a definite practical value. If it has, he should ensure that the time taken is not over-estimated and should decide on a reasonable basis for documentation per hour. The final statement prepared should be as shown in Fig. 184.

Foremen and Assistant Foremen, etc., Section 2. Forms drawn up on the lines of Fig. 185 and Fig. 186 will give a true index of the time spent on each job, as well as revealing any duties performed which are extraneous to the particular function of the individual. It is recommended that forms of this character should be filled in by the individual himself and should run for one month or even two months before being submitted to the investigator.

Printed Forms and Returns, Section 6. In order to ensure that every form and return which is in use is justified, and, if so, to ascertain whether the most economical method is adopted for its reproduction, e.g. printed or duplicated copies, having regard to its user, it is recommended that an authorization form, Fig. 187, be completed in every case, this information deciding the method to be followed for obtaining future supplies.

All technical and clerical staff

ANALYSIS OF DUTIES

(*Note*. The times given are per 4-weekly period, assuming 38 hours per week)

Progress OFFICE

Date 31*st January*, 1940

Duty No.	SUBJECT	Male Clerks					Female Clerks			Total Hours	Time to Remain	Time to be Saved
		Bolton	Haynes	Thompson	Smith	Jones	Harrison	Johnson	Lawson			
(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(J)	(K)	(L)	(M)	(N)
1	Supervision . . .	30					6			36	30	6
2	General Inquiries . .	10		6			1			17	16	1
3	Correspondence . .	20	100							120	120	
4	Registration of Orders				25					25	25	
5	Recording Contractors' Deliveries . . .	24								24	24	
6	Filing					12			152	164	152	12
7	Preparing Specifications .		35	15						50	50	
8	Typing: Material Lists .							100		100	100	
	Letters . .						145			145	145	
	Stock Lists .							12		12	12	
	Specifications .							40		40	40	
TOTAL (Duties 1 to 49 inclusive)	*All Subjects* . . .	152	152	152	152	152	152	152	152	1216	1048	168

FIG. 184. ANALYSIS OF DUTIES (OFFICE ORGANIZATION)

N.B. This example shows a net saving of one clerk, with a margin of 16 hours per 4-weekly period for contingencies

ANALYSIS OF DUTIES OF RATE FIXER

NAME SHOP Week Ending 19

Brief Description of Article	Catalogue No	Order No	Operation for which Price or Time is Being Fixed	Piecework or Premium Bonus Reference No	Number of Hours Occupied (to nearest ¼ hour)							
					Mon.	Tues.	Wed.	Thur	Fri.	Sat.	Sun.	

Note Total possible working hours must be accounted for daily, by showing number of hours absent due to sickness, special leave, etc.

FIG 185. WORK PERFORMED BY RATE FIXERS

ANALYSIS OF DUTIES OF FINISHED WORK INSPECTOR

NAME SHOP Week Ending 19

Brief Description of Article	Catalogue No	Order No.	Quantity		Number of Hours Occupied (to nearest ¼ hour)							
			Accepted	Rejected	Mon	Tues	Wed	Thur	Fri	Sat.	Sun.	

Note Total possible working hours must be accounted for daily, by showing number of hours absent due to sickness, special leave, etc.

FIG 186 WORK PERFORMED BY FINISHED WORK INSPECTORS

APPLICATION FOR NEW FORM

Date

1. Annual Issues of Forms replaced by Proposed Form
2. Annual Issues of Existing Form proposed for Revision
3. Stock
4. Initial Cost of New or Revised Form
5. Subsequent Cost of New or Revised Form
6. Estimated Annual Issues of Proposed Form
7. Last Revision of Proposed Form was dated and approved
8. Specify why Proposed Form is necessary
9. What will be accomplished by Proposed Form that is not now accomplished by some Existing Form or Forms?
10. Has adequate analysis been made to ensure that the design of Proposed Form reflects the underlying actual intention and will therefore attain its object, without need of future revision and expense incident thereto?
11. Will use of Proposed Form entail decreased work, increased work?
12. What other advantages arise from use of Proposed Form?
13. Is Proposed Form temporary or permanent? If temporary give probable maximum duration of its use
14. Give numbers and attach samples of Existing Form or Forms, if any, replaced by Proposed Form
15. Is Proposed Form a consolidation of one or two or more Existing Forms? Give numbers and attach samples
16. Why cannot purpose of Proposed Form be served by use or consolidation of any one or more Existing Forms?
17. Explain specifically the investigation made to determine that no other Existing Form can serve the purpose of Proposed Form
18. Is size of Proposed Form, as given, smallest usable size?
19. How was size determined?
20. What will be the Annual Issue of the Proposed Form? (If Proposed Form is to be used at more than one point attach a statement showing particulars of using points and Annual Issues to said points)
21. Is Proposed Form to be printed, gammetered or multigraphed?
22. Will the majority of Proposed Forms be made out in pen or pencil or type?
23. How frequently will Proposed Form be made out, i e Daily, Weekly, etc ?

FIG 187 AUTHORIZATION FORM

should have their attention specially drawn to the following economies—

(1) The reverse side of scrap paper or obsolete forms (which should be collected and distributed by the stationery stores) should be used for carbon copies, memoranda, or for making calculations.

(2) Envelopes should only be used for strictly confidential matters.

(3) Printed forms should not be left exposed on desks when not in use, but should be kept in drawers or desks until required.

(4) The fullest use should be made of each form.

(5) All forms should be ordered by a clerk who fully understands the requirements, and should be issued by him only to those who are authorized to use them.

Non-productive Staff, Section 15. The preliminary step in this instance is to ask the works accountant to prepare a statement which gives a comparison between the productive and non-productive staffs. Fig. 190 (page 246) shows the manner in which

IMPORTANT

STOP ALL AIR LEAKS

LOOK WHAT IT MEANS IN MONEY

Leak Hole		No. of Cub. Ft. of Air Wasted per Minute	Equivalent Wasted Horse-power	Equivalent Cost per Year*
Diam.	Actual Size			
2 in.		6400	1024	£8192
1 in		1600	256	£2048
¾ in.		900	144	£1152
½ in		400	64	£512
¼ in		100	16	£128
⅛ in.		25	4	£32
$\frac{1}{16}$ in		6	1	£8

* On the basis of the leak taking place for 100 hours per week, 50 weeks per year, and using a figure of 0.5d. per unit as the cost of electricity for power purposes

FIG. 188 COST OF AIR LEAKAGE NOTICE

this statement should be drawn up. It is an invaluable guide and will probably reveal the shops where the greatest weaknesses lie. The investigator will first ascertain the exact duties performed by each non-productive employee, and will briefly tabulate these duties on a single statement similar to the arrangement shown in Fig. 184. A close study of the statement prepared will enable the investigator to decide whether the amount of time occupied on any particular duty is necessary and worth the expenditure which is involved. When his deductions are complete, the investigator will fix as far as practicable what he considers is a reasonable number of man hours to cover the duties of each grade. These figures should be recorded in the rate-fixing department and the accountant asked to supply a weekly return giving the man hours actually charged. These returns should be recorded week by week and thus a close check will be effected.

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FIG. 189. SUGGESTED INDEX FOR WORKS ANNUAL REPORT

Value of Independent Investigation

There is every reason to believe that an intensive, analytical inquiry of this nature by one or more works assistants would prove beneficial in the administration of the works. For instance, there is much that a foreman sees every day which, due to his having been brought up with the practice, may not occur to him as being other than satisfactory, and yet which, in point of fact, may be far removed from the ideal.

In the compilation of an unbiased report the investigators would be

COMPARISON BETWEEN PRODUCTIVE AND NON-PRODUCTIVE STAFF

Note The terms "productive" and "non-productive" require to be defined. A productive worker is one who works to definite basis times, piecework prices, or the equivalent; a non-productive worker is one who, although he may have an indirect bearing on production, is either paid daywork, a lieu rate, or a bonus based on the earnings of a group of men or on the Shop

Shop	Total Staff	Non productive Staff	$\frac{B}{A} \times 100$	Total Wages for Shop	Total Productive Wages for Shop	Total Non productive Wages for Shop	Total Salaries	Total Wages and Salaries (D + G)	Total Non productive Wages and Salaries	$\frac{F}{D} \times 100$	$\frac{G}{H} \times 100$	$\frac{J}{H} \times 100$
REFERENCE LETTER	A	B	C	D	E	F	G	H	J	K	L	M
			%	£	£	£	£	£	£	%	%	%
Assembly	156	39	25	552	436	116	27	579	143	21 0	4·7	24 7
Forge .	45	9	20	159	127	32	9	168	41	20·1	5·4	24 4
Foundry	99	27	27	319	236	83	12	331	95	26 0	3 6	28·7
Machine .	179	26	15	581	488	93	23	604	116	16 0	3·8	19 2
Pattern .	51	9	18	194	171	23	16	210	39	11 9	7·6	18 6
Transport	13	13	100	25	Nil	25	5	30	30	100·0	16·7	100·0
AGGREGATE	543	123	23	1830	1458	372	92	1922	464	20 3	4 8	24·1

FIG 190. ANALYTICAL STATEMENT SHOWING RELATION BETWEEN PRODUCTIVE AND NON-PRODUCTIVE STAFF

SECTION 3 BOILER PLANT AND FUEL CONSUMPTION

Shop	Boiler Plant			Fuel and Water Consumption					
	Type of Boiler	Qty.	Capacity (Lb per Hour)	Coal and Slack (Tons)	Coke—Hard and Gas (Tons)	Firewood (Tons)	Fuel Oil (Gal)	Gas (Cub. Ft.)	Water (Gal.)

SECTION 4. CONSUMPTION OF ELECTRICAL ENERGY

Total K.W.	Power		Lighting	Supply from	Motors			Electric Lamps		Consumption in Units			Cost per Unit	
	A.C. K.W.	D.C. K.W.	A.C. K.W.		No.	H.P. Total	H.P. Per man (All grades)	No.	Total Wattage	Power	Lighting	Total	Power	Lighting
1950	1300	300	350	Central Power Station	795	7623	2·21	3198	312,000	4,882,609	297,550	5,180,159	0·445	0·445

FIG. 192. ANNUAL STATEMENT OF CONSUMPTION OF ELECTRICAL ENERGY

SECTION 9. INDIVIDUAL SHOP REORGANIZATION EFFECTED AND PROGRESSIVE SCHEMES INTRODUCED

Description of Article	Drawing No.	Date of Introduction	Previous Practice	Present Practice	Cost per Unit			Quantity done in 1940	Total Saving for 1940
					Previous	Present	Difference		
					£ s. d.	£ s. d.	£ s. d.		£ s. d.
MACHINE SHOP Reducing Valve	41–8659	4/3/40	Ports slot drilled.	Cast with ports.	1 1	—	1 1	250	13 10 10
Cast Iron U-pipe.	47–2054	6/5/40	Facing Square Flange on Slotting Machine.	Facing Square Flange on Horizontal Boring Machine.	5 1	3 0¾	2 0¼	120	12 2 6

FIG. 193. ANNUAL STATEMENT OF INDIVIDUAL SHOP REORGANIZATION

acting as liaison officers between the employees and the managerial staff, and as such would bring to light valuable information respecting current practices generally.

Spending Sometimes Saves

An important point requires to be mentioned. The elimination of waste does not necessarily mean a cutting down in every direction. Money will sometimes be wisely spent in certain departments by the employment of additional staff, which will result in substantial savings elsewhere, the net results giving a credit balance. Anyone carrying out an analytical investigation must be sufficiently broadminded to be cognizant of such a possibility. A decisive factor to remember, however, is that, unless output is unmistakably increased, there can be no real monetary saving in wages except when expenditure, as represented by the weekly wages bill, is decreased by an amount equal to whatever saving may be claimed. This simple truth is not always appreciated as it should be.

An engineer should always be a firm believer in the principle of the conservation of both mental and physical energy. If he keeps this ever in front of him he will do much towards the elimination of waste in every one of its various forms.

Employees' Suggestions

Every employee should be encouraged to offer suggestions for the more economical and efficient conduct of the firm's business. His intimate contact with a particular job may bring to light some phase of the work which can advantageously be improved upon. If he has the good sense to bring his proposals forward, as all good employees will, he deserves monetary award commensurate with the value of his proposal, and, of course, an appropriate reference should be entered on his staff record card.

Notices to Avoid Waste

The management should never hesitate to put up in prominent places certain boldly printed notices to focus attention on the cost of negligent practices. Fig. 188 shows the type of notice to which reference is made. In this instance attention is drawn to the cost of a leak, according to the size of hole, in a compressed air service. A notice of this kind may, of course, only have a local application within the factory and for that reason its posting should be confined to the immediate area concerned.

Works Annual Report

Paradoxical though it may seem at first, it is convenient to consider within the scope of this chapter the activities of the works during the year. After all, output is closely allied to waste, because if there was a 100 per cent waste the factory would have to close down, and output would automatically cease.

The best way in which output and progress generally can be put on record is to prepare an annual report, for internal reference only, giving all the major features associated with the internal administration of the factory throughout the whole of the year. It is suggested that this report be

furnished on the lines of the index shown in Fig. 189. Examples of Sections 3, 4, and 9 included in Fig. 189 are given in Figs. 191, 192, and 193 respectively. Such a report will prove invaluable.

The cause which is blocking all progress to-day is the subtle scepticism which whispers in a million ears that things are not good enough to be worth improving.

G. K. CHESTERTON.

CHAPTER XVII

SHOP TRANSPORT

Indispensability of Mechanical Equipment

In the production of raw materials, in the converting of raw materials into finished articles, and in the progress of goods from factory to consumer, ordinary handling methods, occurring as they do so frequently in the day's work, represent a high percentage of the costs. Loading and unloading, stacking and tiering, the arrangement of goods on different levels in different parts of the plant or warehouse, and the setting up of heavy machinery, are just a few of the numerous stages at which handling takes place, and where costs are probably waiting to be cut down. It can indeed be said that shop and inter-shop transport in these days no longer consists of so many hand trucks and man-handled trolleys, as used to be the case. It now means the intelligent and systematic use of petrol or electric trucks, tractors, overhead travelling and mobile jib cranes, elevators, and conveyer systems. It may mean even more than that—the proper arrangement of work centres according to the movement of individual components during manufacture.

Whatever form of transport is used, it is important that it should not be overloaded. Consistently to overload is false economy; accordingly an ample reserve of power must always be aimed at in order to minimize breakdowns.

Conveyer Systems

The installation of mechanical and gravity conveyers, straight and spiral chutes, and lifts is almost entirely a matter to be decided by the individual works concerned. Not even general rules can be laid down, as it depends entirely on the layout of the factory and the type of product as to which type of installation is best. All that can be said is that the direction and quantitative flow of material should be carefully studied, and laborious and costly man-handling of goods and material eliminated wherever practicable.

The conveyer should be regarded not only as a means of transport but also as a method of regulating rate of output, for which purpose it is of high value. This value, however, is to be attained only when the provision of the conveyer itself embraces a carefully thought out and possibly elaborate organization for the continuous supply of parts at one end and disposal of the product at the other. Gravity roller conveyer systems, embodying output control, are illustrated in Figs. 194 and 195. The rollers should always be fitted with ball bearings and should be mounted on a sturdy frame. Fig. 196 shows a mechanical chain type conveyer embodying output control. This type has a good deal to commend it and should be fully exploited.

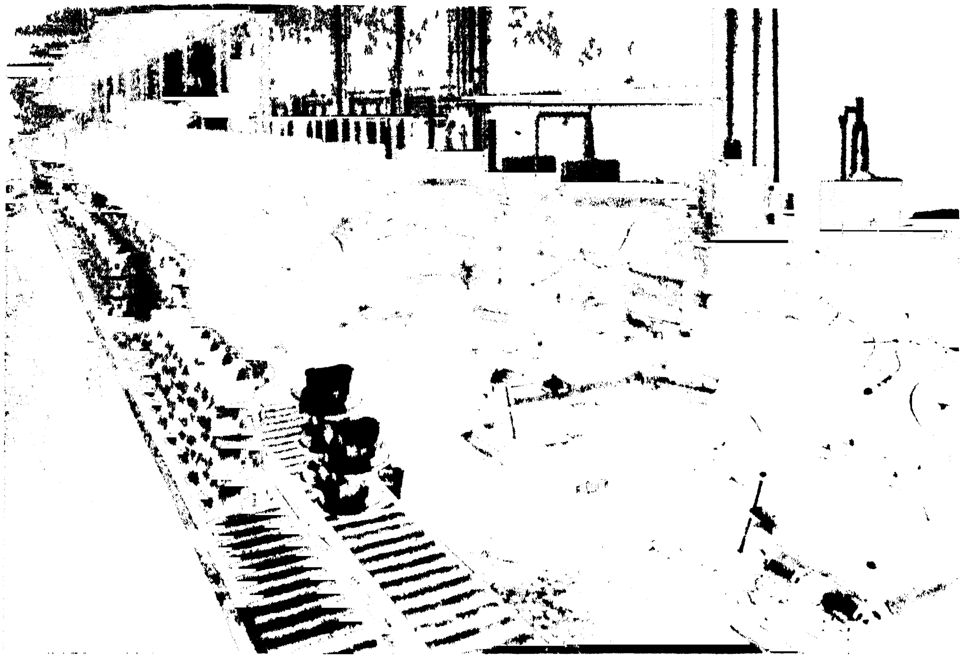


FIG. 194 GRAVITY ROLLER SYSTEM IN USE IN MOTOR WORKS

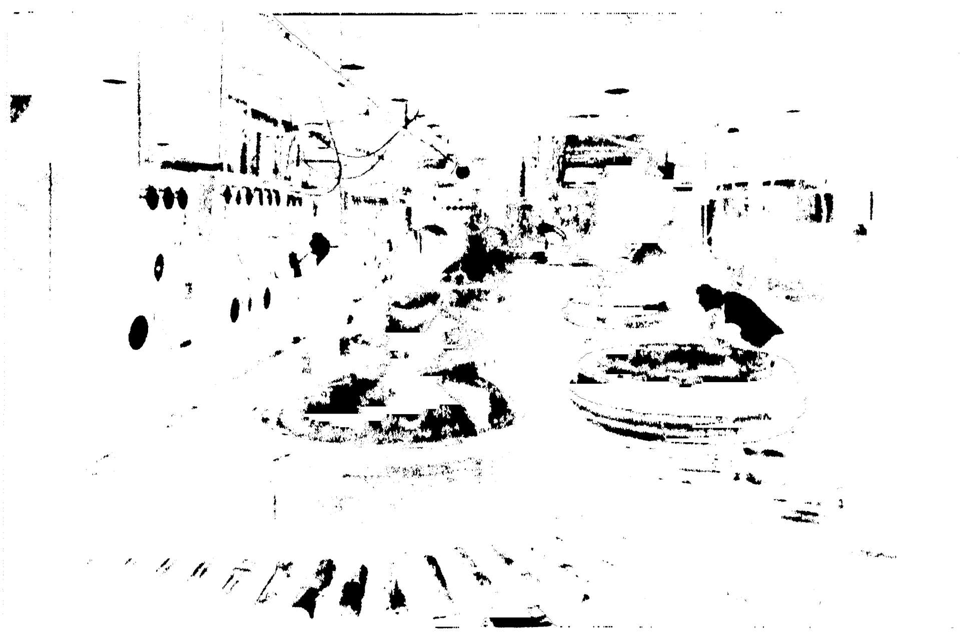


FIG 195 GRAVITY ROLLER SYSTEM IN USE AT TYRE FACTORY (VULCANIZING OF TYRES)

Lifting

Lifting is a form of transport which arises with multi-story buildings, and with buildings which are at different levels. The problem of lifting is a disadvantage of the multi-story building, as it may be considered that any lift is equivalent to a very great length of horizontal traverse. Once in a lift, however, the difference in cost between a short and great elevation is not appreciable, since the cost of power and the time required for lifting are only a fraction of the total. With large-scale production it is sometimes possible to use a continuous type of lift, either vertical or inclined, of the conveyer type, similar to those used for horizontal traverse. In such instances the objections to vertical traverse are greatly lessened.

FIG 196. MECHANICAL CONVEYER SYSTEM

When asking for a quotation from a firm which specializes in conveyer equipment, it will be helpful if information on the lines of the following is supplied to them.

(1) Class of material, giving size of the largest pieces.

(2) Whether material is wet or dry and if it is inclined to be sticky or abrasive.

(3) Weight of the material per cubic foot.

(4) The maximum quantity to be dealt with per hour in tons or cubic yards.

(5) The length of conveyer required —the distance from centre to centre of shafts or from point of feed to point of delivery.

(6) The position of the conveyer—whether horizontal or inclined, and, if the latter, at what angle to the horizontal.

(7) Particulars of feed and whether this will be regular or intermittent, and if at one end only or at intermediate points on the conveyer.

(8) Whether the material is to be delivered at end of conveyer or at intermediate points.

(9) Speed and relative position of motor or countershaft from which the conveyer will be driven. Give diameter of motor shaft or countershaft. It is best in all cases to drive the conveyer from the delivery end.

(10) Type of framework required, i.e. steel or timber, and if it is to be enclosed or open.

It will also be useful if a sketch of the existing layout is supplied.

Overhead Travelling Cranes

One of the great virtues of the electric overhead travelling crane (Fig. 197) is the effective way in which it will cover a large area. Fig. 198 illustrates what may be regarded as good proportions of overhead crane practice.

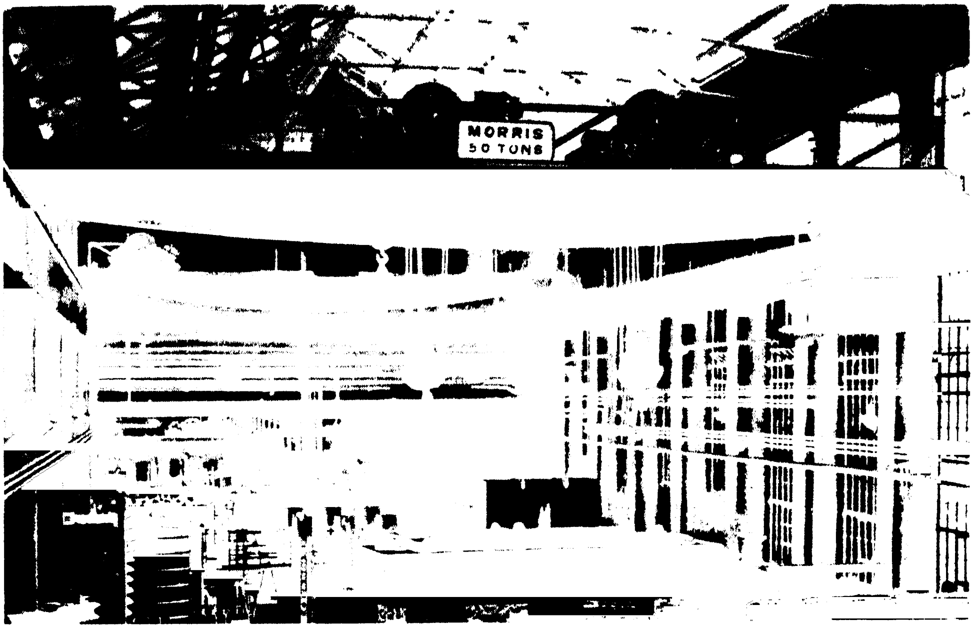
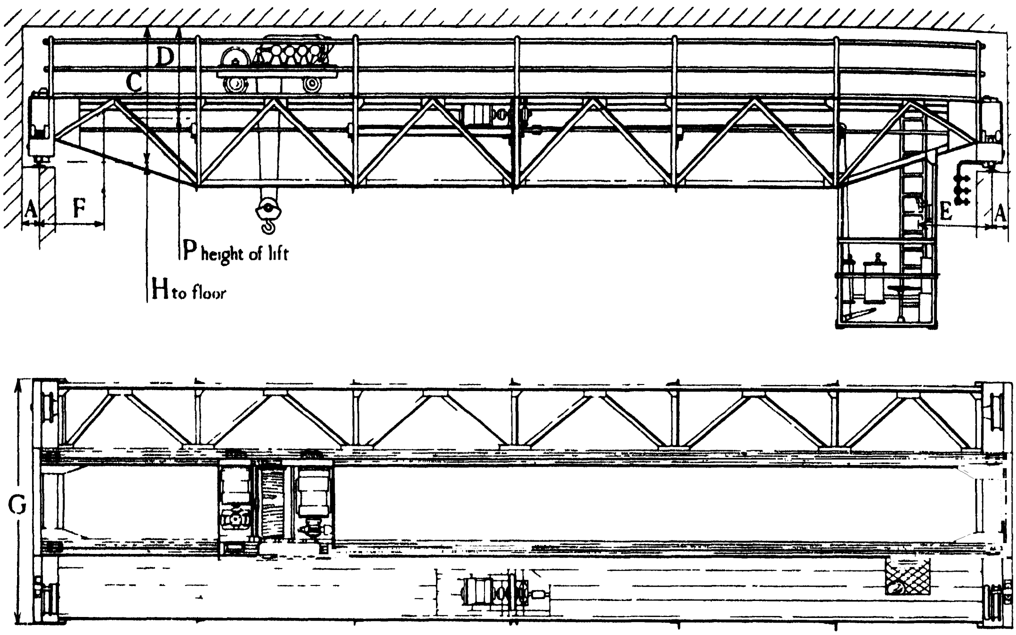


FIG 197 FIFTY-TON CAPACITY OVERHEAD TRAVELLING CRANE

With transporters and other outdoor lifting appliances, long exposure to the weather may cause rotting of timber stays and rusting or corrosion of bolts and other parts. The risk of failure and breakdown from wear and corrosion can be eliminated to a large extent by periodical and thoroughly competent inspection. This fact is not always fully appreciated, too much responsibility being left with crane drivers, fitters, and other unauthorized persons, a contention which is shared by the Chief Inspector of Factories, as evidenced by his reports on crane failures.

So far as lifting tackle is concerned, there are many instructions which require to be carried out. These will almost certainly include the following—

(1) All chains, ropes or lifting tackle should be plainly marked with the safe working load. In the case of multiple slings, reference should be made to the safe working load chart for information regarding the loads which may be lifted when the legs are at different angles. Copies of this notice should, therefore, be kept posted in prominent positions at the places where chains, ropes or lifting tackle are kept, in order that all concerned can make proper use of the appliances.



Working load ..	tons	1	2	3	5	7½	10	15	20	25	30	40	50	60	80	100
All spans P – 35′ 0″	D	3′ 0″	3′ 4″	3′ 7″	4′ 3″	5′ 3″	5′ 6″	7′ 0″	7′ 2″	9′ 0″	9′ 6″	10′ 0″	11′ 0″	12′ 0″	12′ 9″	13′ 6″
Four tramwheels in each	E	2′ 0″	2′ 3″	2′ 4″	2′ 10″	3′ 10″	3′ 10″	3′ 6″	3′ 9″	4′ 3″	4′ 6″	4′ 9″	5′ 0″	5′ 3″	5′ 6″	5′ 9″
end carriage	F	2′ 0″	2′ 0″	2′ 0″	2′ 3″	2′ 9″	2′ 9″	3′ 2″	3′ 2″	3′ 3″	3′ 3″	3′ 5″	4′ 0″	4′ 3″	6′ 0″	7′ 0″
20′ 0″ span	A	7″	7″	7″	8″	8″	8″	9″	10″	11″	11″	11″	1′ 0″	1′ 0″	1′ 2″	1′ 3″
	C	4′ 2″	4′ 9″	4′ 10″	5′ 6″	6′ 4″	6′ 8″	7′ 2″	7′ 6″	7′ 6″	7′ 9″	7′ 9″	8′ 3″	8′ 9″	10′ 0″	11′ 0″
Total weight of crane	tons	4	4½	5	6	7	8	11	13	16	18	21	25	29	35	46
Maximum load per wheel	tons	2	2½	3½	5	6½	8	11	14	17	20	26	32	37	49	31
40′ 0″ span	A	7″	7″	7″	8″	8″	8″	9″	10″	11″	11″	1′ 0″	1′ 0″	1′ 1″	1′ 3″	1′ 4″
	C	4′ 6″	5′ 0″	5′ 3″	6′ 0″	7′ 0″	7′ 3″	7′ 4″	7′ 6″	7′ 6″	7′ 9″	7′ 9″	8′ 3″	8′ 9″	10′ 0″	11′ 0″
Total weight of crane	tons	7	8	9	10	11	12	15	18	21	23	27	32	38	44	56
Maximum load per wheel	tons	3	3½	4½	5½	7	9	13	16	19	22	29	34	40	50	32
60′ 0″ span	A	8″	8″	8″	9″	9″	9″	10″	10″	11″	11″	1′ 0″	1′ 0″	1′ 1″	1′ 4″	1′ 5″
	C	5′ 4″	5′ 9″	5′ 10″	6′ 3″	7′ 2″	7′ 3″	7′ 4″	7′ 6″	7′ 8″	8′ 0″	8′ 6″	8′ 9″	9′ 3″	11′ 0″	12′ 0″
Total weight of crane	tons	10	12	13	14	16	17	20	23	26	29	34	40	45	54	70
Maximum load per wheel	tons	4	5	5½	7	8½	10	14	18	21	24	31	37	43	28	35
80′ 0″ span	A	9″	9″	9″	9″	10″	10″	10″	11″	1′ 0″	1′ 0″	1′ 1″	1′ 1″	1′ 2″	1′ 4″	1′ 6″
	C	6′ 0″	6′ 4″	6′ 5″	6′ 8″	7′ 4″	7′ 4″	7′ 5″	7′ 6″	7′ 8″	8′ 0″	8′ 6″	8′ 9″	9′ 6″	11′ 0″	13′ 0″
Total weight of crane	tons	16	17	18	20	22	24	28	31	34	38	44	50	56	65	84
Maximum load per wheel	tons	5	6	7	9	11	13	16	20	24	27	34	40	48	30	38
100′ 0″ span	A	10″	10″	10″	10″	10″	10″	11″	11″	1′ 0″	1′ 0″	1′ 1″	1′ 1″	1′ 2″	1′ 4″	1′ 6″
	C	6′ 8	7′ 0″	7′ 0″	7′ 3″	7′ 6″	7′ 6″	7′ 6″	7′ 8″	7′ 10″	8′ 3″	8′ 9″	9′ 0″	9′ 9″	12′ 0″	14′ 0″
Total weight of crane	tons	20	22	24	26	30	32	35	39	43	47	53	60	67	78	98
Maximum load per wheel	tons	7	8	10	11	13	15	19	23	26	30	37	44	26	33	40

FIG. 198. PROPORTIONS OF ELECTRIC OVERHEAD CRANES

(2) In no case is the examination period for any appliance in regular use to exceed six months.

(3) No chain, rope or lifting tackle, except a fibre rope or fibre rope sling, should be taken into use in any factory for the first time in that factory unless it has been tested and thoroughly examined by a competent person, and a certificate of such a test and examination made out and kept for reference.

(4) Every chain and lifting tackle except a rope sling should, unless of a class or description exempted by certificate of the firm's chief inspector upon the ground that it is made of such material or so constructed that it cannot be subjected to heat-treatment without risk of damage, be annealed at least once in every fourteen months, or, in the case of chains or slings of half-inch bar or smaller, or chains used in connection with molten metal or molten slag, in every six months, except that chains and lifting tackle not in regular used need be annealed only when necessary.

The adoption of a card record on the lines of Fig. 199 has much to commend it.

CHAINS, ROPES AND LIFTING TACKLE. Mark No

Description Appliance used on

Date Received	Date put into Service	Examination			Steps taken to Remedy Defect	Date of Annealing	Test Certificate		Person Issuing Certificate	
		Date	Name of Person Examining	Particulars of Defect Found			Date	No	Name	Address

FIG. 199. RECORD CARD FOR CHAINS, ROPES, AND LIFTING TACKLE

Trucks versus Tractors

A truck may be defined as a vehicle with a permanently attached platform (Figs. 200 to 208). A tractor may be defined as a vehicle to which four-wheeled and other types of trailers are attached (Figs. 209 to 211). Some consideration is needed to decide which type and which particular design are the more suitable for the class of work to be performed. Clearly a tractor is not so mobile as a truck when it has to turn sharp corners or has to run backwards into an opening. On the other hand the trailers (Fig. 212) can be released quickly and automatically, and as they are comparatively cheap can be freely used, whilst a truck will generally take several minutes to load and unload, and will be out of action during that period.

When purchasing petrol trucks and tractors the following information should be requested from the manufacturer—

(1) Type of engine.
(2) Capacity of engine.
(3) Gear speeds.
(4) Tank capacity.
(5) Size of tyres fitted.

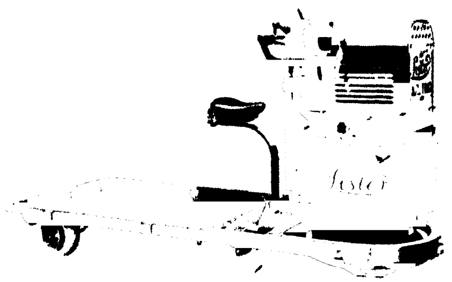


Fig. 200. Fixed Platform Truck Designed for Low Loading

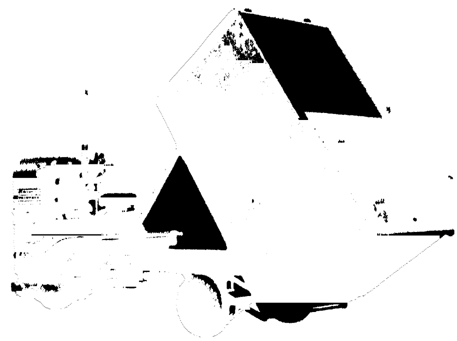


Fig 201 Two-ton Capacity Truck with Screw Lift Tipping Body, Hinged Tailboard, and Detachable Sides

Fig. 202. Truck with Steel End Tipping Body (Normal Position of Body)

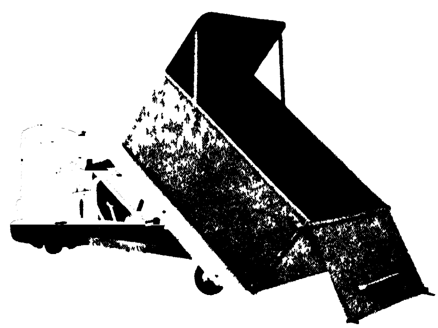


Fig. 203. Truck illustrated in Fig. 202 with Body in Tipped-up Position

Fig. 204. Truck with Low-sided Chassis (In most Works this Type will have a Very Wide Application)

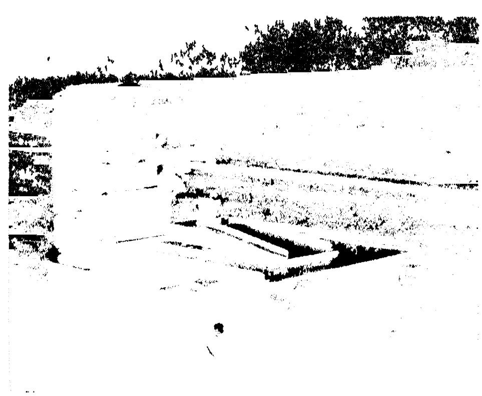


Fig. 205. High Loading Fixed Platform Truck with Slip-way and Coupling Bracket on Platform for Attachment to Articulated Trailer

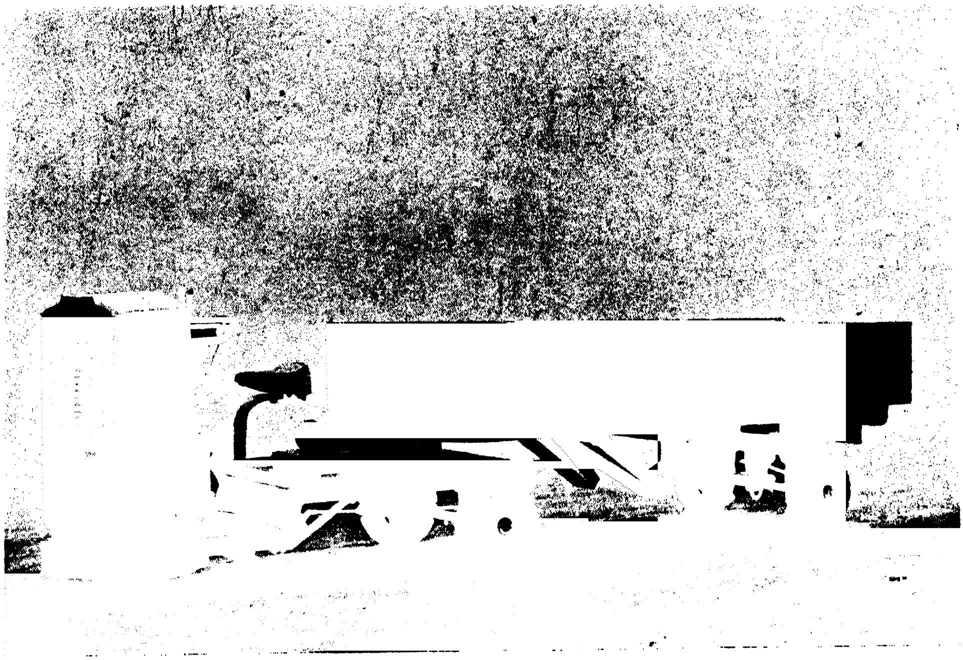


Fig. 206. Truck illustrated in Fig. 205 with Articulated Trailer Attached

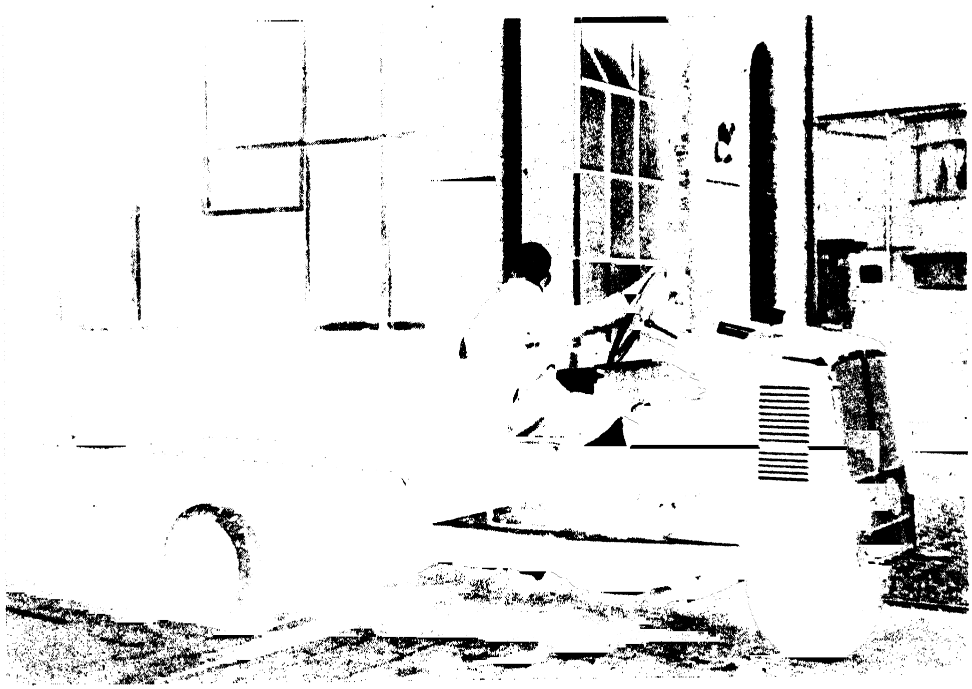


Fig. 207. Fifty-cwt. Capacity Truck with a Turning Radius of 9 ft.

FIG. 208. ARTICULATED BOLSTER TRUCK

FIG. 209. FOUR-WHEELED HEAVY TYPE TRACTOR

FIG. 210. TRACTOR FITTED WITH SHORT PLATFORM TO GIVE GREATER MOBILITY

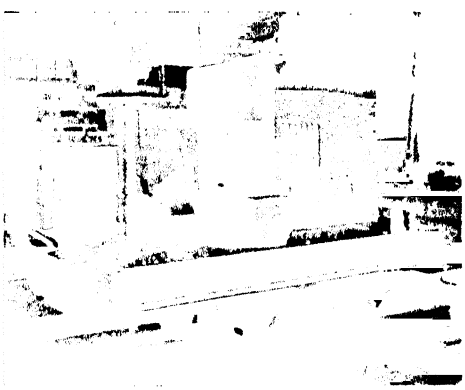


FIG. 211. PETROL RAIL TRACTOR

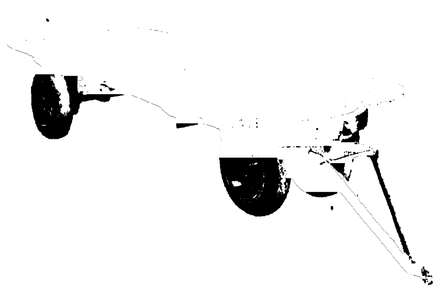


FIG. 212. FOUR-WHEELED TRAILER

(6) Wheel base.
(7) Wheel track.
(8) Turning radius.
(9) Overall length.
(10) Overall width.
(11) Height.
(12) Ground clearance (when loaded).
(13) Chassis weight.
(14) Gross load.

From the purely operating point of view, manœuvrability is very important. Confined spaces frequently have to be negotiated and the turning radius of the vehicle should be as small as possible. Three-wheeled vehicles have the advantage in this respect as they can be turned round in a space which only very slightly exceeds their overall length. The ground clearance when loaded should not be less than 6 in. At the same time the centre of gravity should be as low as possible to ensure a stable vehicle.

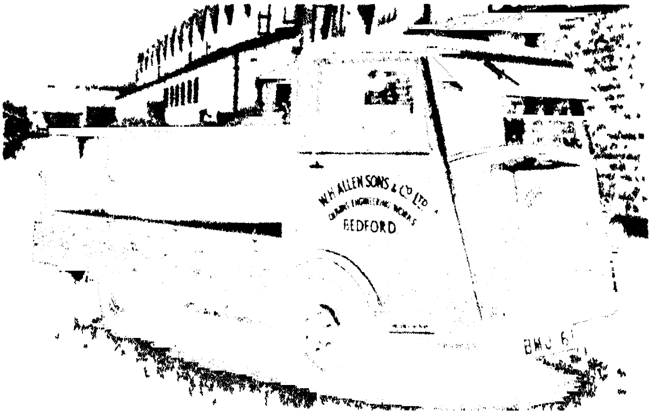


FIG. 213. TWO TON LORRY SUITABLE FOR PRIVATE ROADS WITHIN FACTORY

The extensive use of stillages and trays in conjunction with trucks, in order to eliminate handling, is strongly recommended. Frequently, there will be good use for one or more small lorries within the works. Figs. 213 and 214 show the types suggested. The latter example is provided with

FIG. 214. TWO-TON LORRY WITH DROP-SIDED BODY AND DEMOUNTABLE SWIVELLING HOIST LOCATED FORWARD ON THE OFF SIDE TO ASSIST IN LOADING AND UNLOADING

a small demountable swivelling hoist located forward on the off side.

Time-table

The transport system itself should embrace a carefully drawn up time-table for the collection of all regular loads. Trains and buses are required to run to a time-table and there is no reason why shop transport should not function on similar lines.

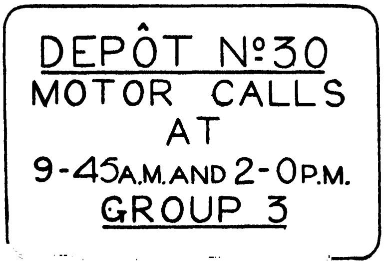


FIG. 215. DEPOT PLATE

In drawing up a time-table for inter-shop transport one has to consider whether it will be advantageous to group together certain depots, which may be situated widely apart but in the vicinity of which consecutive operations have to be performed on the same article, or whether to group together certain shops which are in close proximity almost regardless of their having work in common. Generally speaking, it will be found that the former is the sounder policy, in order to avoid unnecessary loading and unloading. Shops located widely apart may have work common to both, and therefore it is a decided advantage for the motor which picks up material in the one shop to run straight through to the other shops requiring the material, and at the same time include in its journey any other depots which have work in common.

Grouping of Depots

Apart from the emergency motor, referred to later, all motors should work to a prearranged time-table, the calls laid down being consistent with the amount of material involved. In some cases a call may be made once daily at a specified time, in other cases it is possible that a call may be made every hour. These times should be prominently displayed at each registered depot, the distinctive number of which is given, so that all concerned will know exactly when the call will be made and should thus be prepared for it. A steel plate 12 in. × 9 in. × $\frac{1}{8}$ in., with white lettering on a dark background, is a suitable means for identifying depots. The type of information to be included is shown in Fig. 215. The time-tables should be arranged with reasonable spacing between calls, so that ample time is given to dispose of large loads. This spacing will to some extent also permit of the motor being used for transporting extra loads.

No article should be loaded or unloaded at any point other than at a scheduled depot. All motors engaged on inter-shop transport should be given a distinctive group number, e.g. Group 3, this being shown on a detachable board on the front of the motor, and indicating that the particular motor is confined to depots within that group and is working in accordance with the predetermined time-table. A copy of the time-table,

an example of which is given in Fig. 216, should be framed and hung in the motor.

A disc should be used in those few cases where it is not possible to say definitely that one or two calls are required per week. It may be that a month may elapse without anything being required to be transported from a certain depot, and then on another occasion as many as three trips in a week may be required to be made to the same depot, as in the case of a laboratory. In such a case a metal plate 6 in. diameter painted a bright red, with the letter "M" painted on it in black, representing "Motor," should be hung on the depot plate. This will signify that the motor is required, and the driver who is on this particular road will see it, make his call, and hand in the disc to the individual responsible for showing it. On the other hand, if a regular call is arranged, say once a week, this may be preferable even though the driver, when he calls, may find there is nothing for him to move.

DAILY TIME-TABLE—MOTOR GROUP No. 3

Time of Call	*Locality*	*Depot No.*
8.00 a.m.	Receiving Stores	58
9.00 a.m.	Welding Shop	19
9.15 a.m.	Machine Shop (Drilling Section)	16
9.45 a.m.	Brass Foundry	30
10.45 a.m.	Welding Shop	19
11.15 a.m.	Machine Shop (Grinding Section)	7
11.30 a.m.	Erecting Shop	31 & 37
12.15 p.m.	Petrol Station	65
1.30 p.m.	Receiving Stores	58
1.45 p.m.	Welding Shop	19
2.00 p.m.	Brass Foundry	30
2.30 p.m.	Smiths' Shop	40
3.00 p.m.	Machine Shop (Drilling Section)	16
3.30 p.m.	Welding Shop	19
4.15 p.m.	Machine Shop (Automatic Section)	4
5.00 p.m.	Machine Shop (Brass Section)	48

FIG. 216. DAILY TIME-TABLE FOR SHOP MOTOR

Plan of Works Routes

A block plan of the works, indicating the recognized transport routes, with a small circle to denote the location of each depot, and within the circle the registered number of the depot, should be prepared. Included on the plan should be a chart giving the key to each depot. Copies of this composite transport plan and key should be framed and posted in every shop office, and at other desirable points. Preferably, different colours should be used to denote different groups. This plan will be a source of reference, and will enable those concerned to keep the general scheme in front of them with a view to making suggestions for an improved service.

Roads and Tracks

If maintenance charges are to be kept down to a minimum, there must

be no overloading of vehicles, and all roads and tracks must be maintained in excellent condition. It would not be an overstatement to say that the condition of the truck and tractor routes governs the maintenance costs of the vehicles which operate over them. Wood blocks make a good track, but necessitate a foundation of concrete and the use of the same timber throughout. This type of paving is too costly for most truck routes. Unless a good foundation is laid, trouble will be experienced in the blocks hammering through the concrete. If hard and soft timbers are mixed, the soft soon wears and in a short time the track is full of "pot holes."

Blue brick laid on a concrete foundation makes an ideal track from the point of view of durability, but owing to the cost of laying and the difficulty of lifting the bricks in order to attend to water mains, electric cables, etc., it is not considered a practicable proposition.

Reinforced concrete laid to a thickness of $4\frac{1}{2}$ in. to 5 in. makes a perfect track and will last for many years without any attention. Concrete should not be laid where there are drains, electric mains, etc.

Cast-iron plates form a satisfactory type of track for trucks and tractors. There is the advantage too that they can easily be raised for the maintenance of culverts, drains, water mains, gas mains, etc., which are found in profusion in most factories.

The adverse effects of bad roads are numerous, and the heavy maintenance

DATE	1 Lubricate Chassis Nipples	2 Lubricate Springs	3 Gear Box, Drain Flush and Refill	4 Level up Gear Box	5 Back Axle, Drain Flush and Refill	6 Level up Axle	7 Drain Sump and Refill	8 Level up Sump	9 Lubricate Wheel Bearings	10 Lubricate Clutch Race	11 Lubricate Universal Joints	12 Level Steering Box	13 Replacement Nipples	14 Tighten Chassis Bolts and Nuts	15 Brake Liquid Level	16 Top Battery	17 Wash	18 Polish	19 Adjust Brakes	20 Top Shock Absorbers	21 Lubricate Brake Cables	22 Replacement Oil Filter Element	23 Cleaning Oil Filter Element	24 SPEEDOMETER READING OR MILEAGE	

FIG. 217 PETROL, OIL, AND GREASE RECORD FOR MOTOR VEHICLE

charges on transport vehicles which result therefrom are not always appreciated and given the attention they warrant.

Maintenance and Running Costs

Each motor, as well as each trailer, should be given a registered number as soon as it arrives at the works, and all expenses, whether petrol, oil, or maintenance, should be debited to it. So far as supplies of petrol and oil are concerned, arrangements should be made for the motors to be replenished at specified times each day. Spare parts should be stocked, and to facilitate interchangeability it will be necessary to adhere to standard types of vehicles. Systematic and regular inspection of all transport equipment by a qualified mechanic will be a safeguard against irritating breakdowns, as well as keeping repairs down to a minimum. In some instances a spare engine will avoid the risk of dislocation due to a breakdown. In all cases a central garage should be provided and a record maintained on the lines of Fig. 217.

Shunting Locomotives

These may be steam, including "bottle" type locomotives, electric, diesel, or diesel-electric locomotives.

Whatever form of shunting engine is adopted it is essential that there should be ease of control, rapid acceleration, reliability of service, and ample power available. Furthermore, the unit should be capable of being efficiently operated by one man.

Records

Adequate records, as well as systematic maintenance, are necessary if breakdowns are to be avoided. For example, in the case of a steam locomotive it is recommended that a six-monthly examination be carried out, for which purpose reports should be drawn up on the lines of Figs. 218 and 219.

Centralized Control

Centralized control of all mobile transport facilities, whether these be locomotives, motor trucks or tractors, trailers or mobile cranes, has everything to commend it. In the first place each unit can be used to the fullest advantage, and there is not the standing time or unnecessary light running that may occur when it is confined to one shop and is under the jurisdiction of the shop foreman. Secondly, if a unit is not under the jurisdiction of a shop foreman he will lodge a complaint against unsatisfactory service much sooner than if it were under his own control. Hence improved efficiency. It should be quite unnecessary for a shop foreman to ring up the transport officer except in isolated cases, when a motor detailed as the emergency motor, having approximately only 50 per cent of its time engaged on routine work, should be sent.

The adoption wherever possible of mechanical handling methods is an indication of progress, and in a large works there is much money to be saved in a properly organized shop transport system. It can safely be regarded, therefore, as a good investment to choose as the works transport officer someone who is mechanically trained and who possesses considerable intelligence and initiative.

Date

BOILER REPORT FOR LOCOMOTIVE NO

Date put to work after last Heavy Repair	Date of Light Repair since last Heavy Repair	Date Boiler new	Date due for next internal examination

Tubes
Firebox Stays No broken No worn small at heads No of steam tight
Copper Tube Plate
Side Plates
Door Plate
Top Plate
Roof Stay Bolts To change Nuts To change
Shell Plates
Steel Tube Plate
Smoke Box
Estimated time Boiler will run before it requires Heavy Repairs
Remarks

Signed

FIG 218 BOILER REPORT FOR LOCOMOTIVE

Date

EXAMINATION OF LOCOMOTIVE NO

Date of last Heavy Repair	Date of Light Repair since last Heavy Repair

Condition of Motion
Condition of Cylinders
Condition of Frames
Condition of Side or Saddle Tanks
Date of last Piston Examination
Approx date of next Examination

Minimum thickness at top of cylinders when last under repair
L
R

Wheel Tyres
Condition of Flanges Condition of Treads Thickness of Treads

Remarks

Signed

FIG 219 REPORT OF LOCOMOTIVE

CHAPTER XVIII

MOTION AND TIME STUDY

Job Study

Job study has a twofold purpose—

(1) To improve methods and conditions of work, and

(2) To develop a basis for rate-fixing.

The first is known as motion study, the second as time study, each of which may be carried out quite independently of the other.

Motion Study

A motion study of a job in its general elements may reveal many losses and useless motions without any consideration of the time element. There are four possible changes which come through the taking of motion studies: (*a*) operations may be changed and newer and more effective ones found, (*b*) cheaper and more easily worked material may be introduced with equally satisfactory results, (*c*) changes in equipment may be devised, and (*d*) data may always be secured, from which a series of operation schedules may be developed for other items of manufacture.

Whilst the small-scale manufacturer may consider that motion study is too complex to merit his consideration, its elementary principles might prove advantageous to him. If only he can relieve strain and lessen fatigue it will be worth while, as any intelligent supervisor will realize that nothing is gained by making the operators tired as a result of unnecessary activity. After all, even the strongest individual has his physical limitations and no one will wish to make two journeys when one will suffice, nor to put things down just for the pleasure of picking them up again. Yet in effect this is what happens in many factories, and the management wonders why production is so costly. It does not appear to be appreciated that not only is there a senseless waste of time, but the operator is exhausted by unnecessary action and is, therefore, unable to give of his best when engaged upon actual production.

Although motion study may chiefly be considered to centre around the method of doing the work, it must also involve a careful consideration of materials, machines, tools, jigs, fixtures, and other equipment, also working conditions and any other features affecting the particular job. There is much to be said in favour of subjecting the operation to a specific and detailed examination in order to find a better way of doing it, and having done this the most satisfactory solution is likely to result if the observer obtains the co-operation of such individuals as the foreman, jig and tool designer, and in some cases the operator.

Operation Analysis

After recording all that is known about the operation, its various phases should be considered as follows—

1. *Materials*

(*a*) Can cheaper material be substituted?

(*b*) Is the material in the right condition when supplied to the operator?

(*c*) Is the finish of the material too good for the purpose required, or is it not good enough?

2. *Handling of Materials*

(*a*) Do delays occur in the delivery of material to the operator?

(*b*) Can the material be moved a less distance?

(*c*) Can it be handled fewer times?

3. *Tools, Jigs, and Fixtures*

(*a*) Are the tools correctly designed for the work?

(*b*) Are they in good condition?

(*c*) Can tools or fixtures be improved so that less skill is required to perform the operation?

(*d*) Are both hands occupied in the use of the tools or fixtures?

4. *Setting-up of Machine*

(*a*) Is the quantity of details ordered an economical machining quantity?

(*b*) Are drawings, tools, and gauges obtained promptly?

(*c*) Is it economical for the operator to set up his own machine?

(*d*) Are any delays caused in making inspection of the first details produced?

5. *Operation of Machine*

(*a*) Can the operation be eliminated?

(*b*) Can the work be done in multiple?

(*c*) Can multiple operations be carried out?

(*d*) Can the machine speed or feed be increased?

(*e*) Can an automatic feed be used?

(*f*) Can the operation be divided into two or more short operations?

(*g*) Can the sequence of the operation be changed with advantage?

(*h*) Can a more suitable coolant be used?

6. *Operator*

(*a*) What is the operator's base rate?

(*b*) Is a lower-rated operator capable of performing the same operation satisfactorily?

(*c*) Is the operator qualified to perform the operation?

(*d*) Can the operator's performance be improved by further instruction?

(*e*) Can unnecessary fatigue be eliminated by a change in layout, or working conditions, e.g. the introduction of a balanced suspension to carry a portable machine, the use of conveyers or other means for moving materials, or provision for the operator to work in a sitting position?

(*f*) Is supervision satisfactory?

7. *Working Conditions*

(*a*) Are the lighting, heating, and ventilating arrangements satisfactory?

(*b*) Are there any unnecessary hazards involved in the operation?

The foregoing questions show some of the more general elements that must be included in a thorough consideration of the problem of finding the best way in which work may be done. In the case of machines a preliminary

MACHINE TIME RECORD

RECORD COMMENCING ______ MACHINE No ______

TYPE OF MACHINE ______ SHOP No ______

WEEK ENDING	DAY	SHIFT	AT WORK	IDLE — WAITING FOR								OPERATOR OFF DUTY	RESTS INDISPOSITION
				MATERIAL	INSTRUCTIONS	DRAWINGS	SETTER UP	CRANE	OPERATOR	JIGS, TOOLS	ORDERS		
	M												
	T												
	W												
	TH												
	F												
	S												
	S												
	TOTAL												
	M												
	T												
	W												
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	TOTAL												
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	T												
	W												
	TH												
	F												
	S												
	S												
	TOTAL												

ENTER HOURS TO NEAREST QUARTER HOUR.

INSERT 'S' FOR SINGLE SHIFT.
'D' FOR DOUBLE SHIFT
'T' FOR TREBLE SHIFT

AT WORK INCLUDES:- SETTING UP & FIXING JOB & TOOLS BOOKING, CLOCKING ON & OFF, CHECKING, GAUGING, & OBTAINING MATERIALS, DRAWINGS & TOOLS

FIG. 220. MACHINE DATA CARD

survey of a complete group may reveal much valuable information. Such information should be compiled on the lines of Fig. 220.

Specific Analysis

Many instances will arise calling for a particular set of questions. Consider, for example, the cupolamen in an iron foundry. Such a questionnaire as the following might be drawn up.

1. How many men are involved?
2. What is the base rate of pay?
3. What is the average percentage bonus earned?
4. What are their weekly average earnings?
5. What is the basis of payment?
6. Are they paid on input or output?
   (*a*) If the former is it on input of iron only?
   (*b*) If the latter is it on output of good castings only?
7. Is there any variation in staff for low output or other special conditions?
8. Are there any mechanical aids? If so, give particulars.
9. How is the material hoisted?
10. Is any weighing done?
11. Are the men paid on their own recorded weight?
12. What is the total distance the men have to wheel coke and pig iron?
13. Have they any other duties? If so, are these separately priced?
14. Who lines the cupolas with refractory material?
15. What is the rate of pay for these men and what are their average earnings?
16. What is their method of payment?
17. Is bricking done by the cupolamen? If so, in small or large amounts?
18. If bricking is not done by cupolamen, by whom is it done?

Each factory has its own problems and, so far as those involving production are concerned, it is only by analysing them on the lines indicated that the foundations of manufacturing efficiency will be laid.

Therbligs

A therblig is an element of a cycle of motion. There is no difficulty in identifying each of the following therbligs.

(1) Transport loaded.
(2) Transport empty.
(3) Change of direction.
(4) Grasp.
(5) Hold.
(6) Releasing load.
(7) Position.
(8) Pre-position.
(9) Selection.
(10) Search.
(11) Inspection.
(12) Plan.
(13) Use.
(14) Assembly.
(15) Unavoidable delay.
(16) Avoidable delay.
(17) Balancing delay.
(18) Rest for overcoming fatigue.

As a case in point the therbligs used when writing, if it is assumed that a fountain pen is picked up, writing is carried out, and the pen is returned to the ink stand, are as follows—

Names of Therbligs	Steps Used in Writing
(1) Transport empty.	Reaches for pen.
(2) Grasp.	Grasps pen.
(3) Transport loaded.	Carries pen to paper.
(4) Position.	Positions pen for writing.
(5) Use.	Writes.
(6) Transport loaded.	Returns pen to holder.
(7) Pre-position.	Inserts pen in holder.
(8) Release.	Lets go of pen.
(9) Transport empty.	Moves hand to paper.

Principles of Motion Economy

The following rules will form a basis for improving efficiency and reducing fatigue in manual work, but it will be appreciated that the whole of these are not applicable to every operation.

(1) Both hands should begin and complete their therbligs simultaneously.

(2) Both hands should not be idle at the same instant except during rest periods.

(3) Motions of the arms should be in opposite and symmetrical directions instead of in the same direction, and should be made simultaneously.

(4) Hesitation should be analysed and studied, its cause accounted for and if possible eliminated.

(5) The number of therbligs required to do work should be counted, because the best way is almost always a sequence of the fewest therbligs.

(6) Motions should be confined to the lowest possible classifications in order to reduce fatigue.

1st. Finger motions.

2nd. Finger and wrist motions.

3rd. Finger, wrist, and lower arm motions.

4th. Finger, wrist, lower arm, and upper arm motions.

5th. Finger, wrist, lower arm, upper arm, and body motions.

(7) Continuous curved motions are preferable to straight-line motions involving sudden and sharp changes in direction.

(8) Rhythm is essential to the smooth and automatic performance of an operation, and the work should be arranged to permit easy and natural rhythm wherever possible.

Arrangement of the Work Place

A great deal depends on the proper arrangement of the work place. To be successful each of the following points should be given due consideration—

(1) Definite and fixed centres should be provided for all tools and materials.

(2) Controls should be located as close in front of the operator as possible.

(3) Materials and tools should be located to permit the best sequence of therbligs and should be within the normal grasp area.

(4) The height of the work place should preferably be so arranged that alternate sitting and standing at work are easily possible.

(5) A chair of the proper type and height to permit good posture should be provided where possible for every employee.

(6) Gravity feed containers should be used to deliver the material as close as possible to the point of assembly or use. This delivery point should be near the height at which it is assembled, in order to eliminate any lifting or change of direction in carrying the parts to the assembly. Containers for holding supplies should be arranged, preferably at an angle of about 30°.

(7) "Drop" delivery should be used, whereby the operator may deliver the finished article by releasing it in the position in which it was completed, without moving to dispose of it.

(8) The height of the working surface should be equal to the height of the elbow of the operator when standing with the arms relaxed.

(9) The principle of the circular work place should be followed wherever practicable. Work should be confined preferably to the normal work area, i.e. that lying within an arc described on the work placed by

the hand with the forearm extended in front, the upper arm more or less relaxed. It should never extend beyond the maximum work area, which lies within the arc described on the work placed by the hand with the arm fully extended in front, pivoting from the shoulder.

Tools and Equipment

Finally, tools and other equipment require their fair share of attention if efficiency is to be assured. These involve each of the following points—

(1) The hands should be relieved of all work that can be performed more advantageously by the feet or other parts of the body.

(2) Combination tools should be used wherever possible.

(3) Tools and materials should be pre-positioned wherever practicable.

(4) Where each finger performs some specific movement, such as in typewriting, the load should be distributed in accordance with the inherent capacities of the fingers.

(5) Handles such as those used on cranks and large screwdrivers should be designed to permit as much as possible of the surface of the hand to come in contact with the handle. This is particularly true when considerable force is exerted in using the handle. For light assembly work the screwdriver handle should be so shaped that it is smaller at the bottom than at the top.

(6) Levers and handwheels should be located so that the operator can manipulate them with the least change in body position and with the greatest mechanical advantage.

Time Study

Time study means an accurate analysis of the time necessary to perform an operation or a specific part thereof. It involves all the features of close observation which are found in motion study but also includes the time element.

For the purposes of job study, all work may be placed under two general headings—

(1) Work done by machines, and

(2) Work done by operators.

In the main, whereas motion study includes only a study of the work done by operators, time study includes a detailed analysis of both "machine time," or the time taken by the machine in doing its share of the work, and "handling time," which is the time taken by the operator. No management can carry out its duties without information as to what is taking place in the works under its jurisdiction, and time study is the only trustworthy source of some of its most important information.

The carrying out of a time study involves the intelligent analysis of the individual and minute times taken to perform the elementary operations constituting any complete cycle of operations. It is very different from mere "timing," which is the recording of the whole duration of a job, and its importance is more and more widely recognized. Whilst it is usually thought that the fixing of basis times or piecework prices is the main function of time study, the department responsible should, in a well-organized works, also fulfil the functions of securing manufacturing efficiency,

improving design, and reducing fatigue, manufacturing efficiency being the most important of all these. Even in the most up-to-date and progressive factory there is always scope under each of these headings, because what is satisfactory to-day may be hopelessly out of date to-morrow.

Manufacturing Efficiency

Anyone who is called upon to act as a time study observer should realize that his primary duty is to promote manufacturing efficiency. Existing methods must always be closely examined with a view to their improvement, and opportunities must be sought for eliminating operations altogether, or making successive operations simultaneous. Design may be challenged, more particularly if it has been in operation for some time.

It should not be imagined that time studies force operators to work harder in increasing their output. Properly arranged cycles of operations call for no undue exertion on the part of the operator, and the aim of the observer in improving conditions and methods is to eliminate unnecessary work. In many cases, even with a much greater output, a distinct reduction of fatigue can be obtained.

Undoubtedly the best men to carry out the time study, assuming they have been well chosen, are the rate-fixers themselves, working under the direction of the rate-fixing assistant, who in turn should be responsible to the production engineer. By this means they will be organized under a single control directly responsible to the works management, and not under the foremen or superintendents of the departments to which they are allocated.

Secret time studies should never be attempted. At the best the presence of an observer is certain to create uneasiness even though it may be only slight. Accordingly, while not rendering themselves offensively conspicuous, observers should take their time studies in a perfectly open manner and deal at once with any questions raised by the operator under observation, or by others. A position at the side of the operator is better than one directly in front of him. The observer should remain standing when studying a standing operator, but may sit down if the operator is seated.

Type of Operator to be Observed

There would appear to be three types to consider

(1) The first-class or expert operator.

(2) The "average" operator.

(3) Whoever is on the job when the study is made the more usual circumstance. Occasionally this method necessitates the use of factors to "level" the job to the time of the "average" operator or to some other defined type. This means that the study taken on a sub-standard operator will require to be "lowered"; and that on a super-standard operator "raised." Factors such as skill, effort, conditions, and consistency will require to be used in the levelling.

Determining the Number of Observations

The number of observations should be sufficient to give an adequate

statistical sample for computation of the selected element time. They should include all factors influencing the operation, and give evidence of consistency of effort—the greater the consistency the fewer need be the observations.

Handling time will usually be found to fall into three general classes—

(1) The handling of the material that is being worked upon.

(2) The handling of the machine by the operator.

(3) The handling of tools used by the operator in connection with the job.

Time study implies an intense analysis of all these phases of work, and it is useless to commence a time study until a motion study has been applied to all three of these, namely, materials, equipment and methods.

Bedaux System

Ever since its inception in 1911, the Bedaux plan has been generally applied as a basis for wage incentive, but its originator, Mr. Charles E. Bedaux, states that this conception is basically wrong, as the principles are not primarily associated with any form of wage incentive. In reality its principles are those of a highly specialized method of dealing with a time study, although it does actually affect wages. The Bedaux measurement of labour is based on the principle that all human effort may be measured in terms of a common unit, made up of a combination of work and rest, with the proportions dependent upon the nature of the effort and subsequent relaxation required in compensation. The unit is known as the Bedaux Unit of Human Power Measurement and for convenience is always referred to as the "B." As tasks vary, the ratio of work to rest within the unit varies, the unit itself, however, remaining constant. The "B" is not a minute of working time, but a minute in which work and compensating relaxation are combined in the proper proportions. An operation might have a cycle time of 2·4 seconds and be of such a nature as to require an allowance of 150 per cent for relaxation. Then the effort value of the work is ascertained as follows—

$$\frac{2{\cdot}4 \text{ seconds} + 3{\cdot}6 \text{ seconds rest}}{60} = 0{\cdot}1 \text{ B's}$$

Another operation might have a cycle time of 2·96 minutes and be of such a nature as to require an allowance of 50 per cent for relaxation. Then the effort value in this instance equals 4·44 B's (2·96 minutes' work + 1·48 minutes' rest = 4·44 B's).

A production of 800 pieces an hour in the first operation represents $800 \times 0{\cdot}1 = 80$ B's an hour. An equal amount of effective effort on the second operation would produce 18 pieces an hour, since $18 \times 4{\cdot}44$ B's equals 80 B's per hour. If only 17 pieces an hour are produced, then the effective effort has been less ($17 \times 4{\cdot}44$ B's $= 75{\cdot}5$ B's per hour). It will thus be seen that the B is based upon human energy and time. It is independent of type of product, employee, and money value.

To make earnings equitable full consideration must be given to the following factors—

(1) Skill, experience, and responsibility required.

(2) Amount of effort expended.

The Bedaux base rate covers the first factor, and the Bedaux premium covers the second. The standard day's work, i.e. an average output of 60 B's an hour, is the same for every individual, irrespective of sex, occupation, or basic wage. Additional pay is given for additional effort and the amount of this added effort is measured so that no individual is unequally rewarded. B's produced in excess of 60 per hour are termed "Premium B's," the money value of these being equal to the base rate divided by 60.

Office Studies

Motion and time studies can be carried out with good effect on certain kinds of office work, such as the preparation of letters, circulars, and literature for posting, the making up and payment of wages, and work on duplicating machines. The principles applied are much the same as in the works. Great care should be taken, however, in selecting the work for study and in applying the results, allowance being made for each variation of conditions. For example, calculating machine work is not purely mechanical but requires mental effort combined with mechanical work, and any kind of stress or pressure towards faster work is liable to lead to errors. The number of figures and nature of calculations vary, and such variations affect the speed with which the work can be done.

Typewriting, either from recorded speech or from shorthand notes, should not be considered, as both the matter dictated and the character of dictation vary considerably, and these variations affect the possible rate of typewriting. It should only be considered for time study when the typed matter is taken from straightforward printing or notes.

CHAPTER XIX

PAYMENT BY RESULTS

Remuneration of Labour

THE remuneration of labour is the chief problem of all industries. There are other debatable questions, but many of these arise because employees are discontented with their wages.

Simplicity is perhaps the most important demand in wage affairs, as nothing can more easily destroy the confidence of the men than complicated methods of calculation when dealing with earnings. Not less important is the fact that every single employee is entitled to receive, and should receive, every facility for obtaining adequate information as to how his weekly earnings are arrived at.

If it can be accepted that the highly placed executive officer will be encouraged to renew his efforts when rewarded with an advance in salary, can anyone doubt that the application of an incentive system of payment is fundamentally sound when applied to the manual worker?

Payment by results is the general term applied to any system of wage payment in which the wages payable are directly dependent on the output. Such systems are as diverse as they are numerous, though they all have certain administrative features in common. Before expatiating on this subject, however, it will be profitable to refer briefly to other systems which are closely allied to, if not a special type of, payment by results.

Employee Participation in Profits

The oldest kind of employee participation is direct financial participation in the profits of the concern. This may come at regular intervals through some developed plan of profit-sharing, or it may only be carried out at the end of more prosperous years. Profit-sharing implies an agreement between employer and employees, under which the latter receive, over a given period, a predetermined share in the profits of the undertaking in addition to their wages. With such a scheme, the employee knows that he will secure a definite share of whatever profits there may be at the end of a year or other agreed period.

Profit-sharing is often used as a means of arousing the interest of employees whose work does not lend itself to their being placed on a piece-work system. Profit-sharing becomes an ideal preventive for hasty strikes if provision is made in the profit-sharing agreement that only those employees with continuous service shall share in the profits. To go out on strike is naturally regarded as an interruption of continuous service. One of the main objections that employers have raised to profit-sharing is that it does not in reality involve financial participation, inasmuch as losses are not shared by those who share the profits. This must be regarded as one of the weaker points in any profit-sharing plan.

Employee Stock Ownership Schemes

To invest profit-sharing funds in the stock of the company is a more usual feature of profit-sharing schemes. It leads to direct participation in management. Any such plan must be carefully guarded and explained to employees concerned, particularly as regards possible decline in the market value of the securities. Furthermore, unless the number of shares which a given employee may own is considerable, the plan tends to become one for investment of the spare funds of the employee, rather than one of real participation in management.

Service Bonuses

One criticism of the practice of paying employees in a particular grade the same rate of pay, or pay which varies only as their production varies, is that it does not take into account the length of time the employee has been with the firm, his loyalty, and his general knowledge of the industry. This objection is sometimes overcome by the payment of a service bonus. It is usually a percentage of earnings, paid regardless of the type of work which is performed or of the money earned in a given period, and it increases as the length of service increases. Some firms commence payment of service bonuses after six months' employment, whilst others defer the payment for as long a period as five years. The basis of this payment will depend on the type of employee which the firm desires to recognize, and also on the length of service considered necessary to make the employee of added value from a producing standpoint.

Special Bonuses

The distribution of bonuses at Christmas, or other times of the year, in an attempt to share with employees the profits of the firm over a period, has not usually proved a successful form of employee participation. It cannot strictly be regarded as participation in profits, as the distribution of the bonus is really a gift from the firm to its employees. A little consideration will show that bonuses can be worked out for almost any feature of industrial activity. This is particularly true in the case of executives' or foremen's bonuses, some of which appear to be unduly involved.

Premium Bonus and Piecework Systems

It will be found that most industries have adopted one system or another of payment by results. With true piecework, where a fixed price is paid for a given job, an employer knows exactly what his wages costs will be. This system, however, seldom applies in engineering factories where the more prominent systems are (*a*) the piecework system with a guaranteed time wage (100 per cent premium bonus), (*b*) the Halsey, (*c*) the Halsey-Weir, and (*d*) the Rowan system, all of which are premium bonus systems.

Plain Premium System (100 per cent). With the plain premium system the value of the whole of the time or of the money saved is paid to the employee. Consequently there is no reduction in wages cost however large a proportion of the time allowed or "basis time" may be saved.

Halsey Premium System ($33\frac{1}{3}$ per

cent). To enable a bonus to be earned equal to one-third of the time worked, it is necessary to double the estimated time in order to arrive at the appropriate basis time. In view of this, opportunities for earning bonus are continued for a more extended period than under the other premium systems. The Halsey system is simple to work, as is also the calculation of the bonus due.

Halsey-Weir Premium System (50 per cent). Under the Halsey-Weir system the time saved is shared equally between the employer and the employee. To enable bonus to be earned equal to one-third of the time worked, it is necessary to add 66·6 per cent to the estimated time. The simplicity with which the bonus due is calculated, i.e. one-half of the time saved, is one of its recommendations.

Rowan Premium System. This is the only system which has a truly logical feature inasmuch as the bonus paid bears the same relation to the time taken as the time saved bears to the basis time, or $BT : TT :: TS : P$ where BT = Basis Time, TT = Time Taken, TS = Time Saved, and P = Premium or Bonus Hours.

The basis time to yield $33\frac{1}{3}$ per cent bonus is obtained by adding 50 per cent to the estimated time.

The bonus (P) earned $= \dfrac{TT \times TS}{BT}$ or,

percentage bonus earned $= \dfrac{TS}{BT} \times 100$ $= x$ per cent, and bonus (P) $= x$ per cent of TT.

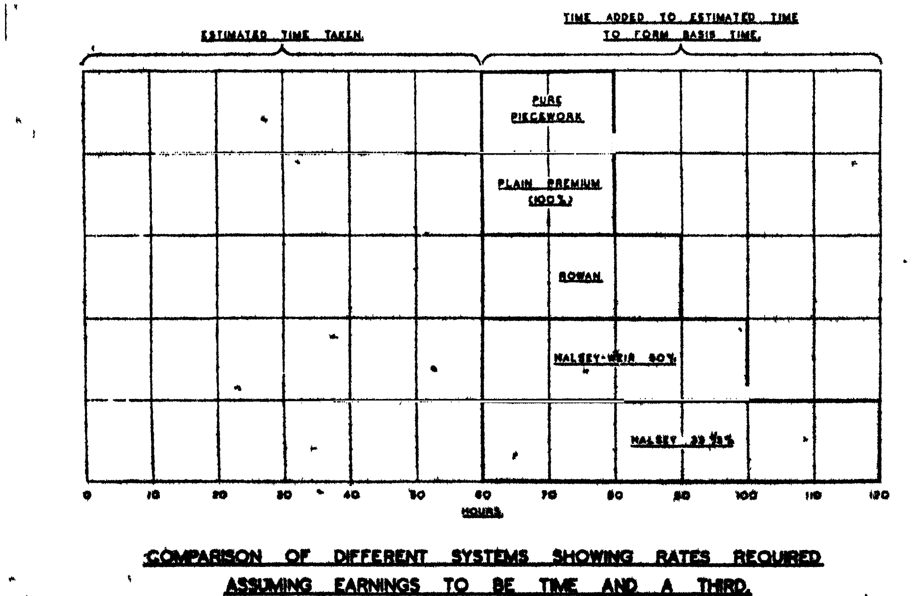


FIG. 221. BASIS TIMES TO YIELD $33\frac{1}{3}$ PER CENT BONUS UNDER VARIOUS SYSTEMS OF PAYMENT BY RESULTS

Fig. 221 shows the time which must be added to the estimated time under each system. A bonus of 33⅓ per cent has been assumed as this is a common percentage allowance in engineering factories.

The following facts should be noted. Under the plain premium system (the piecework system with a guaranteed time rate) the whole of the savings are paid to the employees; under the Halsey and Halsey-Weir systems, arbitrary divisions are made, the bonus payments under all three systems following the straight line law. With the Rowan system the employee is paid a percentage on the time taken equal to that percentage of the basis time which is saved. The more liberal payments under this system when not more than one-half the time has been saved will be observed, as will also the smaller proportion of payments when more than one-half has been saved (Fig. 222). If, however, under the Rowan system the basis time is correctly set in the first instance it is improbable, particularly with machine work, that an operator will exceed 50 per cent bonus.

It is always interesting to compare and contrast various systems of payment by results. Take, for example, the Rowan system and that of the piecework or 100 per cent premium bonus. Tables XVI and XVII show what occurs under each system respectively when increasing percentage bonuses are earned. In Table XVI Columns E and F show that with increasing percentages the time paid for the job decreases; Column G shows how total earnings increase with output; Column H shows how the output increases with increasing percentage; Column J shows the time it would take to do the jobs if only 33⅓ per cent were earned. In Table XVII, Columns B and C show how wages per article decrease proportionately with increased bonus per article (the cost of the article remaining constant); Column F shows how total earnings increase with output; Column G shows how the output increases with increasing percentage. Fig. 223 shows the wages costs and output for varying

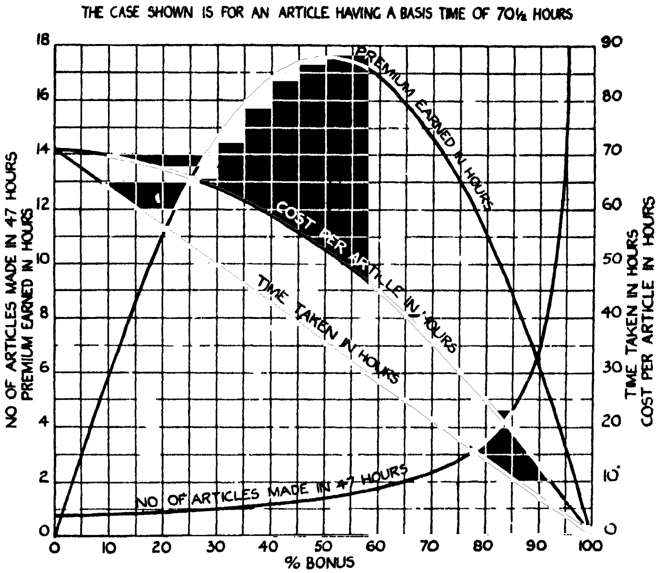


FIG 222 ROWAN PREMIUM BONUS SYSTEM

TABLE XVI

Gross Earnings with Increasing Percentage Bonus under Rowan Premium Bonus System

Basis Time per Article	Time Taken per Article	Time Saved per Article	Premium Bonus Earned per Article	Percentage Bonus per Article	Time Paid for Job	Total Earnings for 47 hours	No. of Articles done in 47 hours	Time it would take to do these Jobs if only 33⅓% was earned
(A) Hours	(B) Hours	(C) Hours	(D) Hours	(E) %	(F) Hours	(G) Hours	(H)	(J) Hours
70½	47	23½	15¾	33⅓	62¾	62¾	1·0	47
70½	42¼	28¼	17	40	59¼	66	1·11	52¼
70½	38¾	31¾	17½	45	56¼	68½	1·21	56¾
70½	35¼	35¼	17½	50	52¾	70½	1·33	62½
70½	31¾	38¾	17½	55	49¼	73	1·48	69½
70½	28¼	42¼	17	60	45¼	75¼	1·66	78
70½	24¾	45¾	16	65	40¾	77½	1·9	89¼
70½	21¼	49¼	14¾	70	36	80	2·21	103¾
70½	17¾	52¾	13¼	75	31	82¼	2·64	124
70½	14	56½	11¼	80	25¼	84¾	3·35	157½
70½	10½	60	9	85	19½	87½	4·47	210
70½	7	63½	6¼	90	13¼	89¼	6·71	315¼
70½	3½	67	3¼	95	6¾	90½	13·43	631¼
70½	—	70½	—	100	—	—	—	—

TABLE XVII

Gross Earnings with Increasing Percentage Bonus under Piecework System

Piecework Price per Article	Wages per Article	Bonus Earned per Article	Percentage Bonus Earned	Operator's Base Rate	Total Earnings for 47 hours	No. of Articles done in 47 hours
(A)	(B)	(C)	(D) %	(E)	(F)	(G)
62s. 8d.	47s. 0d.	15s. 8d.	33⅓	47s.	62s. 8d.	1·0
62s. 8d.	44s. 9d.	17s. 11d.	40	47s.	65s. 10d.	1·05
62s. 8d.	43s. 3d.	19s. 5d.	45	47s.	68s. 2d.	1·09
62s. 8d.	41s. 9d.	20s. 11d.	50	47s.	70s. 6d.	1·13
62s. 8d.	40s. 5d.	22s. 3d.	55	47s.	72s. 10d.	1·16
62s. 8d.	39s. 2d.	23s. 6d.	60	47s.	75s. 2d.	1·2
62s. 8d.	38s. 0d.	24s. 8d.	65	47s.	77s. 7d.	1·24
62s. 8d.	36s. 10d.	25s. 10d.	70	47s.	79s. 11d.	1·27
62s. 8d.	35s. 10d.	26s. 10d.	75	47s.	82s. 3d.	1·31
62s. 8d.	34s. 10d.	27s. 10d.	80	47s.	84s. 7d.	1·35
62s. 8d.	33s. 10d.	28s. 10d.	85	47s.	86s. 11d.	1·39
62s. 8d.	33s. 0d.	29s. 8d.	90	47s.	89s. 4d.	1·43
62s. 8d.	32s. 1d.	30s. 7d.	95	47s.	91s. 8d.	1·46
62s. 8d.	31s. 4d.	31s. 4d.	100	47s.	94s. 0d.	1·5

percentage bonuses under these two systems.

Consider two specific examples—

Assume—

Rate of wages	47s.
Piecework for 1 article . .	6s. 3d.
Basis Time on Rowan system	7 hours

Example 1. Say 10 articles completed in one week of 47 hours.

(*a*) *Piecework*

10 articles completed @ 6s. 3d. each . . .	62s. 6d.

This gives an operator 33 per cent bonus on his wages.

(*b*) *Premium*

Basis Time for 10 articles $= 7 \times 10$	70 hours
Time Taken	47 hours
Time Saved	23 hours
Premium $= \dfrac{TT \times TS}{BT}$	
$= \dfrac{47 \times 23}{70}$ . . .	$15\frac{1}{2}$ hours
Hence wages received for 47 hours	47s.
Premium wages for $15\frac{1}{2}$ hours	15s. 6d.
TOTAL .	62s. 6d.

This gives a bonus of 33 per cent as before.

Example 2. Suppose the operator has experienced some hard luck and has completed only 8 articles in a week of 47 hours.

(*a*) *Piecework*

8 articles @ 6s. 3d. each .	50s.

This will only give a bonus of 6 per cent, or 3s.

(*b*) *Premium*

Basis Time for 8 articles $= 7 \times 8$	56 hours
Time Taken	47 hours
Time Saved	9 hours
Premium $= \dfrac{TT \times TS}{BT}$	
$= \dfrac{47 \times 9}{56}$	$7\frac{1}{2}$ hours
Hence wages received for 47 hours	47s.
Premium wages for $7\frac{1}{2}$ hours	7s. 6d.
TOTAL .	54s. 6d.

This gives a bonus of 16 per cent or 7s. 6d., which is 4s. 6d. more than on piecework.

From the foregoing it will be seen that the Rowan system is more favourable to the operator than the piecework or 100 per cent premium bonus systems when the operator fails to earn the basic $33\frac{1}{3}$ per cent bonus. This fact is clearly demonstrated in Fig. 223.

The Economics of Premium Systems

One of the objections raised to any system of premium bonus payment is the sharing principle which it embodies. There is not much doubt that the reason for this objection is that employees do not understand the principles underlying such systems. It is often wondered why the operator should not be paid for all the time which he may save. In explanation it will be best to consider first an impersonal case. Let it be assumed that a factory has a gas engine consuming 20 cub. ft. of gas per indicated horsepower per hour, but which is underloaded. If the load can be increased up to the point of maximum efficiency, more work will be obtained from the engine, resulting in a saving in overhead expenses. If this is done it cannot be said that the employer would be justified in exercising less care over his gas consumption, and that it would be immaterial if a small quantity were wasted. Instead the consumption should go down, say, to 18 cub. ft. per

indicated horse-power per hour, otherwise approximately 10 per cent of the gas will be wasted.

Everyone will admit the correctness of this reasoning, and to give an employee the whole of the time saved is exactly the same as wasting Whilst it would be unreasonable to expect an employee to make a special effort for no reward, it is equally unfair to expect the employer to do so.

There are some who may think that the employer is sufficiently rewarded by the decrease of overheads. Yet if

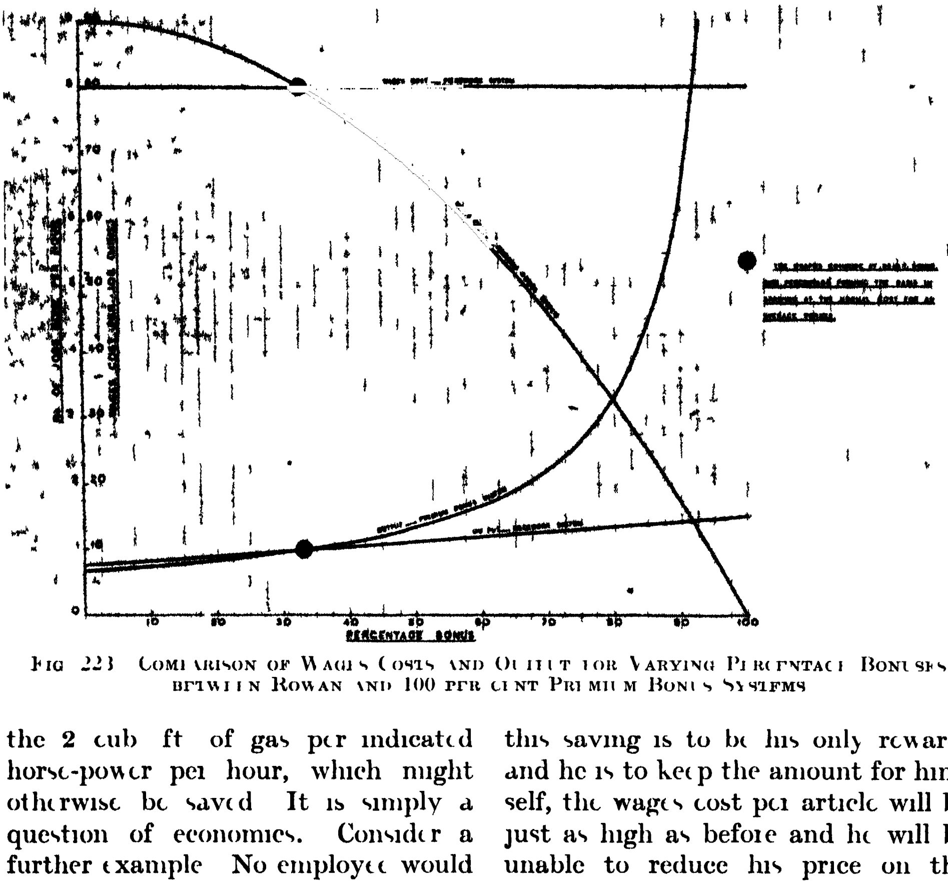


Fig 223 Comparison of Wages Costs and Output for Varying Percentage Bonuses between Rowan and 100 per cent Premium Bonus Systems

the 2 cub ft of gas per indicated horse-power per hour, which might otherwise be saved It is simply a question of economics. Consider a further example No employee would agree that the lessee of a factory should double his ground rent charges because the management was so good that the output had been doubled. But this is exactly what the employee desires when he considers he should exactly double his pay if he doubles his output this saving is to be his only reward, and he is to keep the amount for himself, the wages cost per article will be just as high as before and he will be unable to reduce his price on the market, which will probably result in a loss instead of an increase in trade If, therefore, an increased output can be obtained, together with a reduction in wages costs, there being at the same time an appreciable increase in the total earnings of the operator, there

should be nothing to which the latter should object.

As a general rule it may be taken that, with the pure piecework and 100 per cent premium bonus systems, only the non-variable portion of the workshop expenses, in addition to a portion of the cost of living bonus which may be operative, may be claimed as a saving with increased output. With, say, the Halsey, Halsey-Weir, and Rowan premium bonus systems, both these economies are effected, together with a further saving in direct wages. There are, however, many who favour the 100 per cent premium bonus plan, which often goes under the name of piecework, because of its apparent simplicity of operation and the ease with which the employee can calculate his wages. In spite of this there is much to be said for the other equally well-known forms of premium bonus systems, even though opinions as to the relative merits and demerits of each form often differ and are contradictory in character. It is the author's opinion, after having had direct control of both piecework and premium bonus systems and having discussed them at some length on innumerable occasions with others who have been closely associated but not in actual control, that only those who have had parallel experience to his own can express an authoritative opinion.

If, by agreement, a rate-fixer does not stand continuously with the operator to observe his time closely, the Halsey, Halsey-Weir, and Rowan premium bonus systems certainly have more than ever to commend them because, in the event of a loose time having been inadvertently given, they safeguard themselves; there is no such safeguard with the true piecework and 100 per cent premium bonus systems. At the same time this advantage is no justification for setting "loose" times.

Individual or Collective System

A system is termed "individual" when it refers to employees' efforts, and "collective" when it applies to jobs. The former applies when a separate basis time or piecework price is given for each measurable state of manufacture, whilst the latter applies when work done in different operations and by different men is linked up for payment purposes.

The merits of an individual system over a collective system are worthy of consideration. With the former each operator benefits to the fullest extent for his own effort within the application of the particular system in operation. Under such a system there will of course be cases where a number of men are working together because the nature of their work is such that they cannot work independently of each other, the piecework price or basis time having been arrived at according to the total sum of their individual rates or of their total time. As an example, a group of four men are required to produce forgings under a 2-ton steam hammer, their respective rates being as follows—

Smith .	@ 50s.	per 47-hour week	
Smith's striker .	@ 40s.	,,	,,
Smith's striker .	@ 38s.	,,	,,
Hammer driver .	@ 35s.	,,	,,
TOTAL	163s.		

Supposing the piecework value of the completed work during the week amounts to 220s. and the men work a full week, the percentage balance will be $\frac{220 - 163}{163} \times 100$ per cent $= 35$ per cent. This percentage will be added to their base rates, the smith receiving 50s. + 35 per cent of 50s. and so on, the total amount of bonus shared between the four men being 220 — 163 = 57s. If, however, the striker at 40s. has only worked 45 hours during the week his wages, neglecting bonus, will be $\frac{45 \times 40s.}{47} = 38s.\ 3d.$ In this instance the total wages of the four men for the time worked will be 161s., and with the total value of the work still standing, say, at 220s., the percentage earned will be $\frac{220 - 161}{161} \times$ 100 per cent = 37 per cent. Hence the striker who is rated at 40s. will receive 37 per cent bonus on his time wages of 38s. 3d., whilst the other three men will receive 37 per cent on 50s., 38s., and 35s. respectively. Such an arrangement does not constitute the collective system.

In the collective system an operator may work slowly, either deliberately or because he is below average ability, yet he will receive exactly the same amount of bonus as the rest of his group, who may have to work harder to complete the allotted task in a given time. Perhaps the worst feature of the collective system is the fact that it is frequently impossible to ascertain the true manufacturing cost of any single article. The only safeguard would appear to be to book the actual time worked on that article by each operator. This, however, is not the usual practice where piecework operates.

One advantage of the individual system, whether it be piecework or premium bonus, is that job tickets are each complete in themselves and can be passed forward to the wages office as and when the work is completed. A point which should be emphasized is that with the piecework system it is necessary to revise all existing piecework prices whenever the operator's rate is changed. With premium bonus systems this step is not necessary, as the time allowance for a job remains the same irrespective of the base rate. Premium bonus systems have an advantage over piecework when it is desired to reckon up the amount of work on hand, as its proportions can be more readily estimated from figures representing the hours worked than from those showing the wages to be earned.

Fixing of Basis Times and Piecework Prices

It is most desirable that piecework prices and basis times should be fixed with a definite grade and rate of operator in view. For instance, a piecework price of 1s. fixed for a certain job with an operator rated at 40s. is not applicable to an operator rated at 60s.; similarly with basis times, only to a lesser degree because of their being arranged on a time basis.

There are, however, many cases where apprentices can advantageously be put on work where the original time was fixed for an adult operator. The apprentice or apprentices may work

with or without adult workers. The question arises as to how these varying conditions can be satisfactorily met. A firm may assume that an apprentice is equivalent to 0·5 of a man, in which case it must allow the former twice the man's time. Other firms may allow additional time which is based on the length of apprenticeship already served, e.g.—

Year	Efficiency Factor	Basis Time when adult is allowed 10 hours
1st year	0·5	20 hrs.
2nd year	0·6	16½ hrs.
3rd year	0·7	14 hrs.
4th year	0·8	12½ hrs.
5th year	0·9	11 hrs.

Consider a basis time of 100 hours for an adult. If the man is assisted throughout by a third-year apprentice and a fourth-year apprentice the efficiency factor is $1 + 0 \cdot 7 + 0 \cdot 8 = 2 \cdot 5$, and the time required for completion of the work will be $\frac{100}{2 \cdot 5} = 40$ hours for each individual, or a total time of 120 hours.

Now let us consider an example in which men and apprentices are working together but for different intervals of time. We get the following calculation—

Grade	Ratio of Hrs. Worked	Efficiency Factor	Equivalent Man Hrs.
Adult (A)	30	1·0	30·0
Adult (B)	25	1·0	25·0
3rd-year apprentice	25	0·7	17·5
5th-year apprentice	15	0·9	13·5
Totals	95	–	86·0

Suppose that the basis time for one adult working alone is 200 hours. Then the multiplication factor for each individual's time $= \frac{200}{86} = 2 \cdot 32$. Accordingly, the following individual basis times will require to be allotted in the circumstances mentioned.

Adult (A)	$30 \times 2 \cdot 32$	69·6 hrs.
Adult (B)	$25 \times 2 \cdot 32$	58·0 hrs.
3rd-year apprentice	$25 \times 2 \cdot 32 =$	58·0 hrs.
5th-year apprentice	$15 \times 2 \cdot 32$	34·8 hrs.
Total Basis Time		220·4 hrs.

It is really a better plan to grade the work according to the age of an apprentice and to fix the time accordingly, keeping apprentices only at that age on the work. If the operators are working under the piecework system the piecework price will be arrived at by applying the hourly rate of each operator to the number of hours allowed him, and adding these sums of money together.

It is interesting to note that so far as machine work is concerned it is questionable whether an adult is any faster than an apprentice.

Conversion from One System to Another

If for any reason conversion from one system to another is contemplated it is only natural that every employee will want to be assured that he will not bear any financial loss. Similarly, the employer will not expect to pay out any more wages for an identical output. If the operators are working under a premium bonus system individually, and not collectively, it is possible to have two men on identical work, one of whom may be earning 35 per cent and the other 45 per cent

bonus. The price paid per article at these two percentages is, of course, different and, if straight piecework or even 100 per cent premium bonus is under consideration, the question arises as to the price to be fixed which will be applicable to both operators. If a "mean" price is decided upon, it is clear that one of the operators will receive more and the other less than that to which he has been accustomed.

Prices for entirely new work will be fixed in exactly the same manner as the premium bonus times, and an operator will have three alternatives. He will either continue to work at the same rate as when he was working under the premium bonus system, in which case he will receive more money for the same output as he gave previously; he may conceivably work faster and earn appreciably more than hitherto; or else he may reduce his output to give the same earnings per week as he received in the past. Neglecting this complicated factor the method of application in a straight conversion from one system to another is shown in Table XVIII. The effect on output and earnings under each system is clearly shown in Fig. 224.

TABLE XVIII

CONVERSION OF PREMIUM BONUS SYSTEMS

Proposed Conversion	Method of Application
Halsey $33\frac{1}{3}$ per cent system to Halsey-Weir system	Deduct $\frac{1}{6}$ or 16·6 per cent of basis time
Halsey $33\frac{1}{3}$ per cent system to Rowan system	Deduct $\frac{1}{4}$ or 25 per cent of basis time
Halsey $33\frac{1}{3}$ per cent system to Plain Premium system	Deduct $\frac{1}{3}$ or $33\frac{1}{3}$ per cent of basis time
Halsey-Weir system to Halsey $33\frac{1}{3}$ per cent system	Add $\frac{1}{5}$ or 20 per cent of basis time
Halsey-Weir system to Rowan system	Deduct $\frac{1}{10}$ or 10 per cent of basis time
Halsey-Weir system to Plain Premium system	Deduct $\frac{1}{5}$ or 20 per cent of basis time
Rowan system to Halsey $33\frac{1}{3}$ per cent system	Add $\frac{1}{3}$ or $33\frac{1}{3}$ per cent to basis time
Rowan system to Halsey-Weir 50 per cent system	Add $\frac{1}{9}$ or 11·1 per cent to basis time
Rowan system to Plain Premium system	Deduct $\frac{1}{9}$ or 11·1 per cent from basis time, assuming plain premium rate is given in terms of time

Chargemen's Premium Bonus

Chargemen controlling a group of men may or may not be included in the basis times or piecework prices, though the better plan, undoubtedly, is to include them. In either case chargemen should be paid the same percentage as the men whom they control. If it is desired to include their allowance in a piecework price, for example, it will require to be worked out as follows—

$$\text{Chargeman's allowance} = \frac{\text{Chargeman's base rate} \times (1 + \text{normal allowance on time taken})}{\text{Standard week in hours} \times \text{Average number of men controlled}}$$

Assume chargeman's base rate = 60s., normal allowance = $33\frac{1}{3}$ per cent, standard week = 47 hours, average

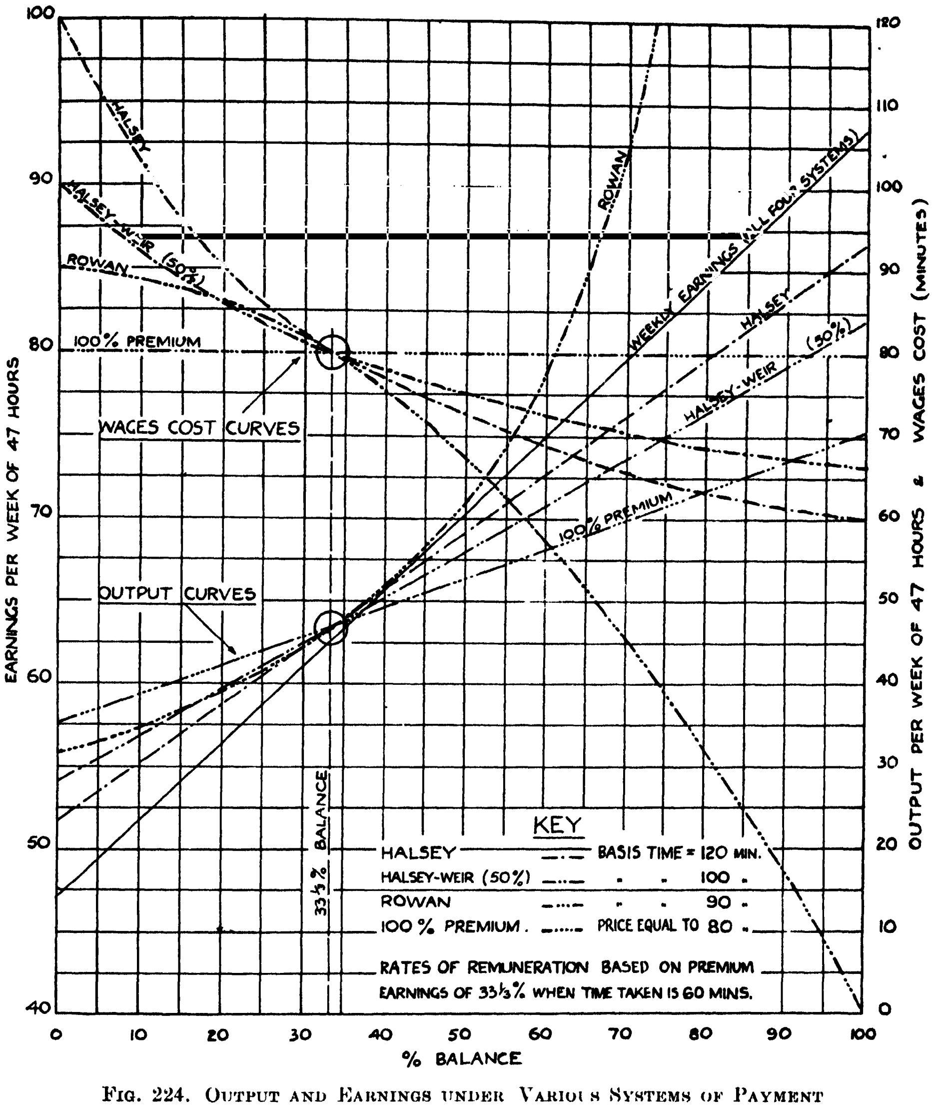


FIG. 224. OUTPUT AND EARNINGS UNDER VARIOUS SYSTEMS OF PAYMENT

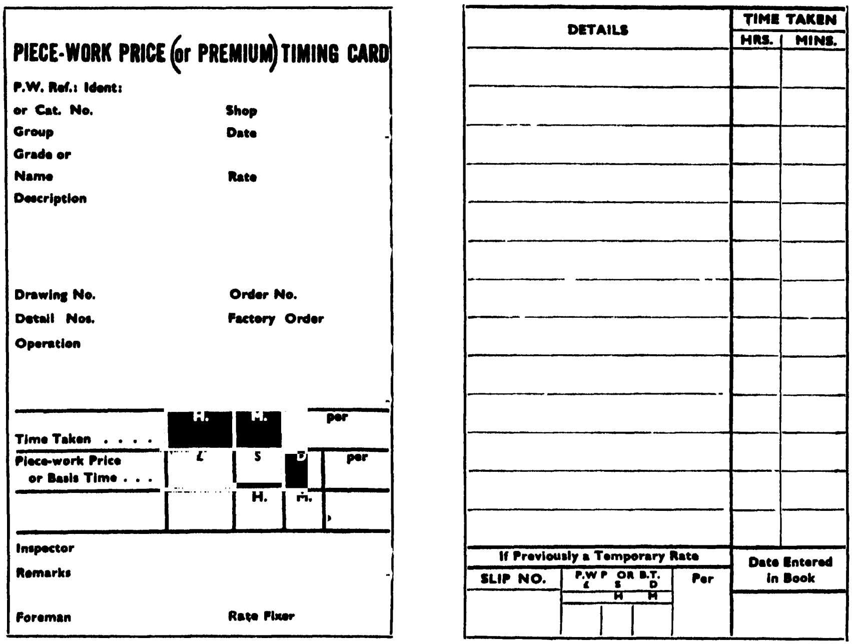
number of men controlled = 20, then we have $\frac{60s. \times 12d. \times 1\cdot33}{47 \times 20} = 1d.$ per hr. This means that for every man hour recorded during timing operations 1d. must be added to cover the chargeman's allowance.

Payment of Non-productive Staff

It is appreciated that there are certain workers to whom a system of payment by results cannot always be efficiently applied. Such staff includes foremen, supervisors, machine setters-up, and finished work inspectors, whose

duties require them to organize. Under normal conditions their payment will be assessed on their value to the firm.

As far as practicable, all manual workers should be placed on whatever system of payment by results is works as a whole. A workable scheme is to fix a minimum bonus and subsequently an additional $2\frac{1}{2}$ per cent for every 5 per cent increase in actual output. It must not be overlooked, however, that some productive work-


PIECE-WORK PRICE (or PREMIUM) TIMING CARD
P.W. Ref.: Ident:
or Cat. No. Shop
Group Date
Grade or
Name Rate
Description
Drawing No. Order No.
Detail Nos. Factory Order
Operation
H. M. per
Time Taken . . . .
£ S D per
Piece-work Price
or Basis Time . . .
H. M.
Inspector
Remarks
Foreman Rate Fixer

DETAILS
TIME TAKEN
HRS. MINS.
If Previously a Temporary Rate
SLIP NO. P.W.P. OR B.T. £ S D H M Per
Date Entered in Book

(*front*) (*back*)

FIG. 225. BASIS TIME CARD
(Suitable for either piecework or premium bonus)

operative in the factory. Those grades which are indirectly associated with productive workers, as for instance crane drivers, slingers, furnacemen, and labourers, should receive a bonus based on the earnings of the group of men with whom they work. The scales should be varied according to the degree of the association. Sometimes a group of indirect workers will not be attached to any shop, in which case their scale should be based on the average percentage of bonus earned in the ers will be almost entirely dependent upon their labourers, and in such circumstances it is only logical that the latter should receive the same percentage bonus as the productive men. In all cases the system of payment should ensure complete control of the man hours worked by the indirect workers compared with those of the productive workers.

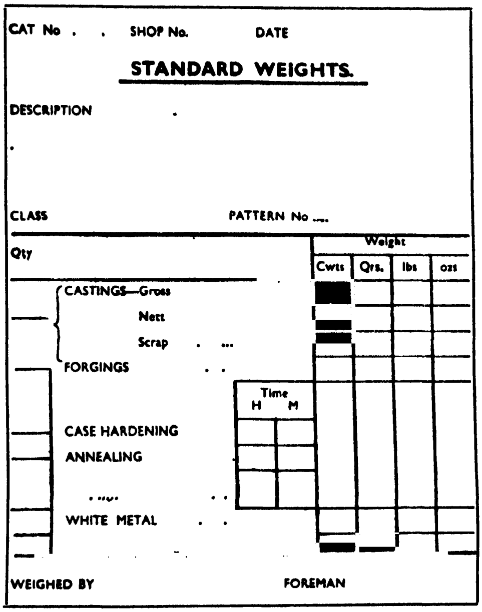
Registration of Basis Times

The system recommended for recording information respecting premium

bonus times or piecework prices may be summarized as follows —

In the first place, the rate-fixer allotted to a certain department or shop will be advised that the time of a new job is required to be ascertained. If the production planning department has not already done so, it will be the foreman's duty to stipulate the correct setting up of the tooling, and it will also be his duty to advise the operator that the rate-fixer will be carrying out a time test. With the time test completed in the manner adopted by the particular factory, i.e. arrived at by accurate time study or by a number of visits made to the operator during the progress of the work, the rate-fixer should complete a basis time card, Fig. 225, giving detailed particulars of the total time taken.

If it is customary, as in many engineering factories, to take the overall time rather than make a detailed time study, the Rowan system would appear to have a great deal in its favour, inasmuch as the principle under which it operates, viz. the percentage bonus paid being strictly proportional to the time taken (see Fig. 222), safeguards itself in the event of a liberal basis time having been given. With any other premium or piecework system there is no safeguard which is equally effective, and if a faulty initial basis time allowance or piecework price has been made this must stand for all time once the time or price has been agreed with the employee or employees directly affected. The only chance of rectifying the error is to endeavour to find an improved method of manufacture, thereby allowing the present method to fall into disuse and be cancelled. If the time allowed or basis time is approved by the operator when offered to him by his foreman, the latter should sign the basis time card and the rate-fixer should pass it forward to his superior. If finally approved,


CAT No. . . SHOP No. DATE

STANDARD WEIGHTS.

DESCRIPTION

CLASS PATTERN No ...

Qty — Weight: Cwts | Qrs. | lbs | ozs

CASTINGS—Gross

Nett

Scrap

FORGINGS

Time: H M

CASE HARDENING

ANNEALING

WHITE METAL

WEIGHED BY FOREMAN

FIG. 226. STANDARD WEIGHT CARD

the time should be registered in the appropriate basis time book, of which there should be three copies for every distinct group of operators, one copy being kept by the chargeman, one by the rate-fixing department, and one by the works costs accountant.

Certain grades will be paid on a weight basis and in these cases standard weights will need to be registered on cards, Fig. 226, and entered in books, Fig. 227. Basis time books (or cards, if preferred) are an

Catalogue No., Identification No., Drawing No., or Class	Description of Article		Weight					Per
			T	C	Qr.	Lb	Oz	
19/5080	Brass Bush, 2½ in dia., 3½ in long, 1½ in hole	G	—	—	1	20	0	
		N			1	12	0	Ten
		S			—	8	0	
19/5125	Brass Bush, 3½ in dia., 7¾ in long, 1½ in hole	G		1	3	24	0	
		N		1	3	0	0	Ten
		S		—	—	24	0	

G = Gross
N = Net
S = Scrap

FIG. 227. STANDARD WEIGHT BOOK

Clock No   Name   Week ending   19

CHARGE TICKET

Charge   (Work for one charge only to be entered on this ticket)

Catalogue, Ident., or Slip No.	Article	Operation	Qty	Weight T	Weight C	Weight Qr	Weight Lb	P.W. Price or Time Taken		P.W. Amount or Basis Time £	s. H	d. M

TOTAL			
Less charged on A/c W.E.			
„ „ „ W.E.			
TOTAL (Current week)			
Workshop Expenses			

GROUP STAMP

FIG. 228. WAGES TICKET (INDIVIDUAL SYSTEM)

(*Note.* This charge ticket is shown suitable for either piecework or premium bonus)

Week Ending		Piecework Time								Piece work Sheet No	Reference to any other P W Sheet	Rate	Daywork Time							
Clock No	Name	Sun	M	T	W	Th	F	S	Total				Sun	M	T	W	Th	F	S	Total

Fig 229 Group Time Book

important unit in any wages system and it is essential that they should be maintained in an up-to-date, correct, and systematic manner. If spring-covered books are used, additions, amendments, and cancellations can more readily be made. If the individual system is in operation, it is preferable that either a charge ticket (Fig. 228) or a premium card (see Chapter XXII) should be issued to the employee for each separate job and each separate operation. Where a card system is in use the operator should clock on and off the card at the commencement and finish of the job respectively.

				RATE		
CLOCK No.						
NAME						
Other Group Nos.						
	£	s.	d.	Total Wages		
Wages brought forward				£	s.	d.
HOURS	AMOUNT					
Actual						
Extra for: Overtime, Sunday & Nights				Gang No.		
P.W. Balance						
Cost of Living Bonus						
Total for Week						
Group Stamp						

FIG. 230. PIECEWORK WAGES TICKET FOR EMPLOYEE (GROUP WORKING)

Booking of Group Time under the "Collective" Piecework System

To record the movements of employees from group to group and from gang to gang (transfers which of necessity arise), and to supply information for compiling piecework wages tickets, the daily time worked by each employee in various gangs should be recorded in a group time book, Fig. 229, the time being entered daily by a shop clerk. The total time for each employee should balance with his wages tickets and time recording card. From the group time book the shop clerk should prepare the piecework wages tickets. Fig. 230 should be used

Shop..........

Group No.......... Job No..........

a. Total of Job tickets			
,, ,, Wages			
P.W. Balance			
b. Extra for overtime			
c. Cost of Living Bonus			
Total, a, b, and c			
Wages brought forward			
Total for week			
% deduction			
TOTAL			

CLOCK Nos. ON JOB

Foreman ....

FIG. 231. SUMMARY PIECEWORK TICKET FOR GROUP WORKING

for each employee in the gang showing his rate, hours, and wages. Fig. 231 is a summary of the work done by the gang, upon which ticket should be entered the total piecework amount, the total wages, and the clock numbers of the employees engaged in the gang.

Work not completed at the end of the week should be charged on account, the form shown in Fig. 232 being suitable for recording purposes. The amount paid on account is usually only equivalent to the day wages, the full balance being paid on completion of the job. In certain cases, however, for a large job, some bonus, say 25 per cent, may be paid on account if justified by the average balance normally earned. A duplicate of the incomplete work form should be kept in the shop, and on completion of the work the amounts and dates drawn on account on previous weeks should be entered on the piecework charge ticket.

INCOMPLETE WORK

PIECEWORK TICKET Employee's Clock No Shop

Name W E

Charge to Allocation Code No

Piecework Reference	Operation and Description of Work	Quantity	Price	£	s	d

Job Commenced W E Total Piecework Earnings

Less Paid on Account

Hours occupied Amount

Total

Add Workshop Expenses

FIG. 232. INCOMPLETE WORK TICKET

Employee's Work Book

Where an employee is working under the individual system it is recommended that he should be supplied with a work book to enable him to book his own work and thus record the wages earned. The type of book suggested is illustrated in Fig. 233. It

Week Ending 194

Article	Operation	Job Ticket No	Qty	Ident No or Cat No	Premium System		Charge
					Basis Time in Hours	Time Taken in Hours	

	Record of Time Worked							Total Hours Worked
	Sun	M	T	W	Th	F	S	
Ordinary Time								
Overtime								

Totals						
Basis Time (Hours)	Time Taken (Hours)	Time Saved (Hours)	Premium Bonus (Hours)	Wages		
				£	s	d

Fig 233 Employee's Work Book

is further suggested that each book should contain information similar to the following—

EMPLOYEE'S WORK BOOK

Shop Name

Group No. Clock No.

The use of this book is optional. It is the property of the Firm and must not be taken away from the premises. It is provided for the use of any employee who wishes to keep an accurate record of his work and wages.

The following are PIECEWORK PERCENTAGES earned and/or entered for week ending							
Group	Per cent	Group	Per cent	Group	Per cent	Group	Per cent
1		6		11		16	
2		7		12		17	
3		8		13		18	
4		9		14		19	
5		10		15		20	

Mr. Shop average

No. Shop For Works Accountant

FIG. 234 PERCENTAGE BONUS FORM

Premium Bonus Cards. The following rules will be of assistance in keeping premium cards in correct order, and in calculating wages.

Unless working with a face card (i.e. a premium clocking card to which charge cards, each showing work of less than 5 hours' duration, are attached) all employees must "clock on" as soon as they receive their premium card, and, when the job is finished, "clock off." This must be done to the nearest quarter of an hour. No premium card must be "clocked off" until another one has been received from the chargeman, which must be "clocked on" at the same time. If one job is left incomplete in order to perform work upon another, the incomplete job must be "clocked off," and when recommenced must be "clocked on," this procedure being repeated until the job is completed.

When from any cause anyone is delayed for 30 minutes or more through the temporary breakdown of machinery or plant, the premium card for the job in hand must be "clocked off" and a delay card, filled in and certified by the chargeman, "clocked on." Before recommencing work the delay card must be "clocked off" and a premium card "clocked on."

All premium cards for finished jobs must be handed in to the chargeman as soon as the job is finished.

Employees must only enter the time taken in lead pencil on each premium card. In no circumstances must a blank premium card be "clocked on," each premium card being clearly written out before the commencement of the job.

Calculating Bonus. [Assuming, for instance, the Rowan premium system is in operation.] The following explanation is given as to the manner in which premium bonus is calculated—

If you save ¼ of the basis time you are paid time-and-a-quarter for the actual hours worked; if you save ½ of the basis time you are paid time-and-a-half for the actual hours worked, and so on. The following is an easy

method of calculating your premium bonus: Multiply the Time Taken by the Time Saved, and divide by the Basis Time. The answer is your premium bonus hours.

Group Percentages

The percentage bonus earned by each group should be supplied week by week by the accountant on a percentage bonus form (Fig. 234). This information should be transferred to a graph as shown in Fig. 235, those portions of the curve falling below the previous year's average being shown dotted, and the average for each completed quarter being registered on the right. It is an invaluable record, showing at a glance the trend of bonus earnings and also enabling a quick decision to be given where special allowances are required to be made, e.g. attendance at works' committee and similar meetings. A copy of the return should be passed into the shop concerned to enable the foreman to see what is taking place in this respect and to enable him to make a check against the volume of work on hand should the percentage fall below normal.

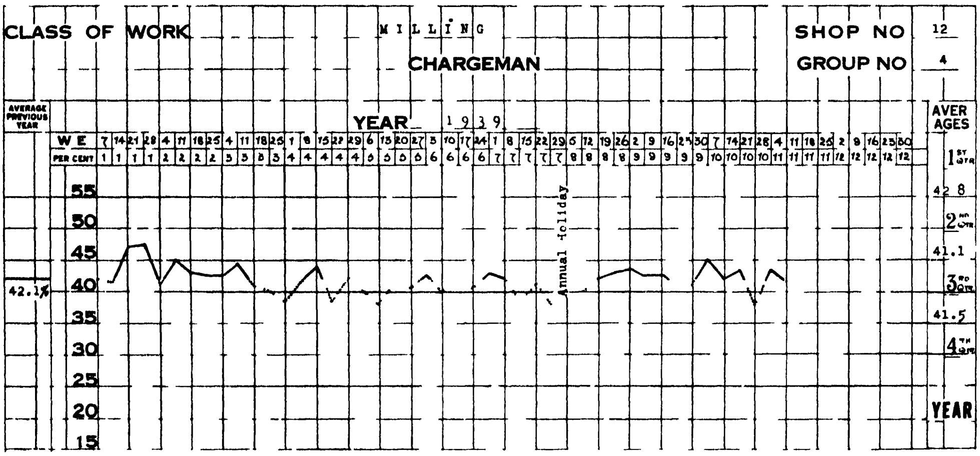


FIG 235 GRAPH SHOWING GROUP PERCENTAGE EARNINGS

Overtime Return

Closely allied to payment by results is the amount of overtime and night shift working which takes place. As these involve added expense compared with the ordinary day shift, it is advisable to exercise a close check by instituting a weekly return giving the essential particulars as well as indicating whether the overtime is due to productive or maintenance work. The return recommended is shown in Fig. 236.

Daywork

Whilst it is recommended that a system of payment by results should be adopted for all who are employed on manual work, there are usually a few grades, e.g. storesmen and watchmen, who cannot be brought within such a scheme. In these cases the base rate only should be paid and a daywork card, Fig. 237, used for recording

NIGHT SHIFT AND OVERTIME RETURN

Shop No. ... . Week ending .

Day	No. of Men on Night Shift	PRODUCTION "P" (Overtime worked outside the normal shifts to increase output, exclusive of overtime resulting from part of week's ordinary rostered working, or overtime under Section "M")			MAINTENANCE "M" (Overtime necessitated in normal times to enable ordinary working of the shops to be carried on without delay: e.g. attending to belts, oiling machinery, sweeping up shop, cleaning out furnaces, etc.)		
		No. of Men	Total Hours Worked	Work Engaged Upon	No. of Men	Total Hours Worked	Work Engaged Upon
SUNDAY							
MONDAY							
TUESDAY							
WEDNESDAY							
THURSDAY							
FRIDAY							
SATURDAY							
TOTALS		Total hours worked during week on "P"		Total No of men on overtime during week on "P"	Total hours worked during week on "M"		Total No of men on overtime during week on "M"

SIGNED

FIG. 236. WEEKLY OVERTIME RETURN

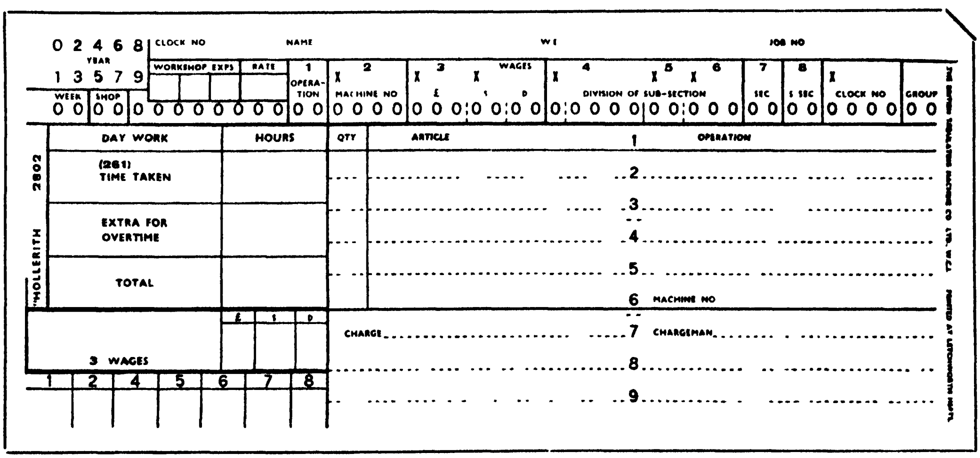

0 2 4 6 8 CLOCK NO NAME WI JOB NO
YEAR
1 3 5 7 9 WORKSHOP EXPS RATE 1 OPERATION X 2 MACHINE NO X 3 X WAGES £ S D X 4 X 5 X 6 DIVISION OF SUB-SECTION 7 SEC 8 S SEC X CLOCK NO GROUP
WEEK SHOP
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
DAY WORK HOURS QTY ARTICLE 1 OPERATION
(261) TIME TAKEN 2
EXTRA FOR OVERTIME 3
4
TOTAL 5
6 MACHINE NO
£ S D
CHARGE 7 CHARGEMAN
3 WAGES 8
1 2 4 5 6 7 8 9
2802 "HOLLERITH"
THE BRITISH TABULATING MACHINE CO LTD. W.C.1
PRINTED AT LETCHWORTH HERTS.

FIG. 237. EMPLOYEE'S DAYWORK CARD

the time worked at the day rate. It will be appreciated that certain of the blank spaces require to be used by the works accountant in the calculation of the individual's wages, the latter being done in conjunction with the operator's time recording card.

(5) To note where improvements may be made.

(6) To observe that documents are economically used.

(7) To turn out for correction any documents which are noticeably incomplete.

WAGES PAYBILL

Shop Week ending

Clock Number	Name	Grade	Rate	Deductions National Insurance Health	Unemployment	Actual Hours	Gross Amount	Net Amount for Payment
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)

FIG. 238. WAGES PAYBILL

Scrutiny of Wages Documents

The collection and superficial scrutiny in the rate-fixing office of wages documents, in transit to the wages office, is recommended for the following reasons

(1) To indicate how documents are progressing.

(2) To detect delays.

(3) To note that they are written out by authorized clerks and not by chargemen or other employees.

(4) To note that there are no departures from the recognized system.

(8) To turn out documents for allowances or other reasons.

(9) To expedite completion of the paybill by centralized control.

(10) To give the rate-fixing office staff a general knowledge of the situation.

Payment of Wages

With regard to the paybill, it is recommended that it be compiled as shown in Fig. 238. A wages table, Fig. 239, giving information extending over the range of rates applicable,

WAGES TABLE FOR FORTY-SEVEN HOURS PER WEEK

RATE PER WEEK

Hours	40s. 10·2128d. per hour £	s.	d.	42s. 10 7234d. per hour £	s.	d.	44s. 11·2340d. per hour £	s.	d.	46s. 11 7447d. per hour £	s.	d.
¼	0	0	3	0	0	3	0	0	3	0	0	3
½	0	0	5	0	0	5	0	0	6	0	0	6
¾	0	0	8	0	0	8	0	0	8	0	0	9
1	0	0	10	0	0	11	0	0	11	0	1	0
2	0	1	8	0	1	9	0	1	10	0	1	11
3	0	2	7	0	2	8	0	2	10	0	2	11
4	0	3	5	0	3	7	0	3	9	0	3	11
5	0	4	3	0	4	6	0	4	8	0	4	11
6	0	5	1	0	5	4	0	5	7	0	5	10
7	0	5	11	0	6	3	0	6	7	0	6	10
8	0	6	10	0	7	2	0	7	6	0	7	10
9	0	7	8	0	8	1	0	8	5	0	8	10
10	0	8	6	0	8	11	0	9	4	0	9	9
1	0	9	4	0	9	10	0	10	4	0	10	9
2	0	10	3	0	10	9	0	11	3	0	11	9
3	0	11	1	0	11	7	0	12	2	0	12	9
4	0	11	11	0	12	6	0	13	1	0	13	8
5	0	12	9	0	13	5	0	14	1	0	14	8
6	0	13	7	0	14	4	0	15	0	0	15	8
7	0	14	6	0	15	2	0	15	11	0	16	8
8	0	15	4	0	16	1	0	16	10	0	17	7
9	0	16	2	0	17	0	0	17	9	0	18	7
20	0	17	0	0	17	10	0	18	9	0	19	1
1	0	17	10	0	18	9	0	19	8	1	0	7
2	0	18	9	0	19	8	1	0	7	1	1	6
3	0	19	7	1	0	7	1	1	6	1	2	6
4	1	0	5	1	1	5	1	2	6	1	3	6
5	1	1	3	1	2	4	1	3	5	1	4	6
6	1	2	2	1	3	3	1	4	4	1	5	5
7	1	3	0	1	4	2	1	5	3	1	6	5
8	1	3	10	1	5	0	1	6	3	1	7	5
9	1	4	8	1	5	11	1	7	2	1	8	5
30	1	5	6	1	6	10	1	8	1	1	9	4
1	1	6	5	1	7	8	1	9	0	1	10	4
2	1	7	3	1	8	7	1	9	11	1	11	4
3	1	8	1	1	9	6	1	10	11	1	12	4
4	1	8	11	1	10	5	1	11	10	1	13	3
5	1	9	9	1	11	3	1	12	9	1	14	3
6	1	10	8	1	12	2	1	13	8	1	15	3
7	1	11	6	1	13	1	1	14	8	1	16	3
8	1	12	4	1	13	11	1	15	7	1	17	2
9	1	13	2	1	14	10	1	16	6	1	18	2
40	1	14	1	1	15	9	1	17	5	1	19	2
1	1	14	11	1	16	8	1	18	5	2	0	2
2	1	15	9	1	17	6	1	19	4	2	1	1
3	1	16	7	1	18	5	2	0	3	2	2	1
4	1	17	5	1	19	4	2	1	2	2	3	1
5	1	18	4	2	0	3	2	2	2	2	4	1
6	1	19	2	2	1	1	2	3	1	2	5	0
7	2	0	0	2	2	0	2	4	0	2	6	0
8	2	0	10	2	2	11	2	4	11	2	7	0
9	2	1	8	2	3	9	2	5	10	2	7	11
50	2	2	7	2	4	8	2	6	10	2	8	11
1	2	3	5	2	5	7	2	7	9	2	9	11
2	2	4	3	2	6	6	2	8	8	2	10	11
3	2	5	1	2	7	4	2	9	7	2	11	10
4	2	5	11	2	8	3	2	10	7	2	12	10
5	2	6	10	2	9	2	2	11	6	2	13	10
6	2	7	8	2	10	1	2	12	5	2	14	10
7	2	8	6	2	10	11	2	13	4	2	15	9
8	2	9	4	2	11	10	2	14	4	2	16	9

Hours	47s. 12 0000d. per hour £	s.	d.	48s. 12 2553d. per hour £	s.	d.	50s. 12 7660d. per hour £	s.	d.	52s. 13·2766d. per hour £	s.	d.
¼	0	0	3	0	0	3	0	0	3	0	0	3
½	0	0	6	0	0	6	0	0	6	0	0	7
¾	0	0	9	0	0	9	0	0	10	0	0	10
1	0	1	0	0	1	0	0	1	1	0	1	1
2	0	2	0	0	2	1	0	2	2	0	2	3
3	0	3	0	0	3	1	0	3	2	0	3	4
4	0	4	0	0	4	1	0	4	3	0	4	5
5	0	5	0	0	5	1	0	5	4	0	5	6
6	0	6	0	0	6	2	0	6	5	0	6	8
7	0	7	0	0	7	2	0	7	5	0	7	9
8	0	8	0	0	8	2	0	8	6	0	8	10
9	0	9	0	0	9	2	0	9	7	0	9	11
10	0	10	0	0	10	3	0	10	8	0	11	1
1	0	11	0	0	11	3	0	11	8	0	12	2
2	0	12	0	0	12	3	0	12	9	0	13	3
3	0	13	0	0	13	3	0	13	10	0	14	5
4	0	14	0	0	14	4	0	14	11	0	15	6
5	0	15	0	0	15	4	0	15	11	0	16	7
6	0	16	0	0	16	4	0	17	0	0	17	8
7	0	17	0	0	17	4	0	18	1	0	18	10
8	0	18	0	0	18	5	0	19	2	0	19	11
9	0	19	0	0	19	5	1	0	3	1	1	0
20	1	0	0	1	0	5	1	1	3	1	2	2
1	1	1	0	1	1	5	1	2	4	1	3	3
2	1	2	0	1	2	6	1	3	5	1	4	4
3	1	3	0	1	3	6	1	4	6	1	5	5
4	1	4	0	1	4	6	1	5	6	1	6	7
5	1	5	0	1	5	6	1	6	7	1	7	8
6	1	6	0	1	6	7	1	7	8	1	8	9
7	1	7	0	1	7	7	1	8	9	1	9	10
8	1	8	0	1	8	7	1	9	9	1	11	0
9	1	9	0	1	9	7	1	10	10	1	12	1
30	1	10	0	1	10	8	1	11	11	1	13	2
1	1	11	0	1	11	8	1	13	0	1	14	4
2	1	12	0	1	12	8	1	14	1	1	15	5
3	1	13	0	1	13	8	1	15	1	1	16	6
4	1	14	0	1	14	9	1	16	2	1	17	7
5	1	15	0	1	15	9	1	17	3	1	18	9
6	1	16	0	1	16	9	1	18	4	1	19	10
7	1	17	0	1	17	9	1	19	4	2	0	11
8	1	18	0	1	18	10	2	0	5	2	2	1
9	1	19	0	1	19	10	2	1	6	2	3	2
40	2	0	0	2	0	10	2	2	7	2	4	3
1	2	1	0	2	1	10	2	3	7	2	5	4
2	2	2	0	2	2	11	2	4	8	2	6	6
3	2	3	0	2	3	11	2	5	9	2	7	7
4	2	4	0	2	4	11	2	6	10	2	8	8
5	2	5	0	2	5	11	2	7	10	2	9	9
6	2	6	0	2	7	0	2	8	11	2	10	11
7	2	7	0	2	8	0	2	10	0	2	12	0
8	2	8	0	2	9	0	2	11	1	2	13	1
9	2	9	0	2	10	1	2	12	2	2	14	3
50	2	10	0	2	11	1	2	13	2	2	15	4
1	2	11	0	2	12	1	2	14	3	2	16	5
2	2	12	0	2	13	1	2	15	4	2	17	6
3	2	13	0	2	14	2	2	16	5	2	18	8
4	2	14	0	2	15	2	2	17	5	2	19	9
5	2	15	0	2	16	2	2	18	6	3	0	10
6	2	16	0	2	17	2	2	19	7	3	1	11
7	2	17	0	2	18	3	3	0	8	3	3	1
8	2	18	0	2	19	3	3	1	8	3	4	2

Hours	54s. 13·7872d. per hour £	s.	d.	56s. 14 2979d. per hour £	s.	d.	58s. 14 8085d. per hour £	s.	d.	60s. 15·3191d. per hour £	s.	d.
¼	0	0	3	0	0	4	0	0	4	0	0	4
½	0	0	7	0	0	7	0	0	7	0	0	8
¾	0	0	10	0	0	11	0	0	11	0	0	11
1	0	1	2	0	1	2	0	1	3	0	1	3
2	0	2	4	0	2	5	0	2	6	0	2	7
3	0	3	5	0	3	7	0	3	8	0	3	10
4	0	4	7	0	4	9	0	4	11	0	5	1
5	0	5	9	0	5	11	0	6	2	0	6	5
6	0	6	11	0	7	2	0	7	5	0	7	8
7	0	8	1	0	8	4	0	8	8	0	8	11
8	0	9	2	0	9	6	0	9	10	0	10	3
9	0	10	4	0	10	9	0	11	1	0	11	6
10	0	11	6	0	11	11	0	12	4	0	12	9
1	0	12	8	0	13	1	0	13	7	0	14	1
2	0	13	9	0	14	4	0	14	10	0	15	4
3	0	14	11	0	15	6	0	16	1	0	16	7
4	0	16	1	0	16	8	0	17	3	0	17	10
5	0	17	3	0	17	10	0	18	6	0	19	2
6	0	18	5	0	19	1	0	19	9	1	0	5
7	0	19	6	1	0	3	1	1	0	1	1	8
8	1	0	8	1	1	5	1	2	3	1	3	0
9	1	1	10	1	2	8	1	3	5	1	4	3
20	1	3	0	1	3	10	1	4	8	1	5	6
1	1	4	1	1	5	0	1	5	11	1	6	10
2	1	5	3	1	6	3	1	7	2	1	8	1
3	1	6	5	1	7	5	1	8	5	1	9	4
4	1	7	7	1	8	7	1	9	7	1	10	8
5	1	8	9	1	9	9	1	10	10	1	11	11
6	1	9	10	1	11	0	1	12	1	1	13	2
7	1	11	0	1	12	2	1	13	4	1	14	6
8	1	12	2	1	13	4	1	14	7	1	15	9
9	1	13	4	1	14	7	1	15	9	1	17	0
30	1	14	6	1	15	9	1	17	0	1	18	4
1	1	15	7	1	16	11	1	18	3	1	19	7
2	1	16	9	1	18	2	1	19	6	2	0	10
3	1	17	11	1	19	4	2	0	9	2	2	2
4	1	19	1	2	0	6	2	1	11	2	3	5
5	2	0	3	2	1	8	2	3	2	2	4	8
6	2	1	4	2	2	11	2	4	5	2	5	11
7	2	2	6	2	4	1	2	5	8	2	7	3
8	2	3	8	2	5	3	2	6	11	2	8	6
9	2	4	10	2	6	6	2	8	2	2	9	9
40	2	5	11	2	7	8	2	9	4	2	11	1
1	2	7	1	2	8	10	2	10	7	2	12	4
2	2	8	3	2	10	1	2	11	10	2	13	7
3	2	9	5	2	11	3	2	13	1	2	14	11
4	2	10	7	2	12	5	2	14	4	2	16	2
5	2	11	8	2	13	7	2	15	6	2	17	5
6	2	12	10	2	14	10	2	16	9	2	18	9
7	2	14	0	2	16	0	2	18	0	3	0	0
8	2	15	2	2	17	2	2	19	3	3	1	3
9	2	16	3	2	18	5	3	0	6	3	2	7
50	2	17	5	2	19	7	3	1	8	3	3	10
1	2	18	7	3	0	9	3	2	11	3	5	1
2	2	19	9	3	1	11	3	4	2	3	6	5
3	3	0	11	3	3	2	3	5	5	3	7	8
4	3	2	0	3	4	4	3	6	8	3	8	11
5	3	3	2	3	5	6	3	7	10	3	10	3
6	3	4	4	3	6	9	3	9	1	3	11	6
7	3	5	6	3	7	11	3	10	4	3	12	9
8	3	6	8	3	9	1	3	11	7	3	14	1

will be of material assistance in compiling the paybill.

Actual payment of wages should preferably be effected in small transparent envelopes, say 4¾ in. × 3 in., in which each note and coin is clearly visible. If this is done and a small slip is included showing the amount payable, the employee is able to verify the money with the amount on the slip without recourse to opening the envelope. By this simple method, if the envelope has been opened, the employer is not held responsible for any alleged discrepancy between the amount shown on the slip and the actual money in the envelope. The slips can readily be obtained by perforating and folding back a portion of the paybill at the time the pay sheet is prepared, and making a carbon copy of the amounts. The work of putting up wage packets is particularly suited to girls, and an efficient girl will count the money and put it into the pay envelopes at a rate approximating 300 per hour—over a maximum period, say, of four hours.

CHAPTER XX

DRAWINGS, DESIGN, AND INITIATION OF MANUFACTURE

Difference between Functional and Working Drawings

BROADLY speaking, this chapter covers the range of responsibilities of the chief designer. He may or may not control the development section, which in some industries is equally as important as, if not more important than, the designing section. In either case the question will arise as to where development finishes and designing begins. Probably the best solution is the establishing of two distinct offices in the evolution of any design. The first will be mainly concerned with calculations and performance data; the second with production and customer considerations. Development, therefore, involves the preparation of what are called functional drawings, whilst design involves the preparation of working drawings. Whereas functional drawings usually call for high technical attainments, the major requirement with working drawings is a considerable knowledge of workshop processing together with an understanding of the firm's policy. In the design of complex products made in very small numbers to special requirements, the two offices must frequently be telescoped into one in the interests of speed and economy.

Engineering products which it is proposed to place on the market in quantities as a standard article, such as lawn mowers, bicycles, and motor cars, require further consideration before mass production can be authorized. Sample products need to be made from the actual manufacturing equipment which has been set up to produce the components in accordance with the working drawings. Afterwards the first assembly of these sample components must be submitted to suitable performance tests.

The Drawing Office

The outstanding importance of the drawing office in any industrial organization scarcely needs any emphasis. If it is concerned with the design of the marketable product it may be said at once that the success of the enterprise largely depends upon the competency of the technical staff involved. If it is concerned with the design of jigs and fixtures, as well as any other equipment to be used within the works, the efficiency of the factory is greatly enhanced by capable and knowledgeable draughtsmen. In both cases it will be clear that careful selection of staff is essential, and only those who have the highest credentials, both in their practical experience and their theoretical attainments, should be considered. In no circumstances should anyone who has not served a full apprenticeship or pupilage in the shops be considered for a position in the drawing office—that "holy of holies." More than one

firm has closed down in the past because it has been badly served by its technical staff engaged in the drawing office.

With larger firms the drawing office should, where it concerns the product, come under the jurisdiction of a chief designer or technical assistant who is independent of the works. In this event, the works manager will act as a "contractor" and, though he may not dictate the policy so far as it affects the design, he should not hesitate to voice his opinion on any questionable point, more particularly where he foresees a cheaper method of manufacture without loss of efficiency. There is much to be said for such a clear division of authority, as it leaves the works manager free to concentrate on the diverse problems with which he is daily confronted. Any equipment to be used within the works is essentially a matter for the plant drawing office. Accordingly, this office should be regarded as a separate entity from the office responsible for the design of the product, and should in all cases come under the plant and machinery engineer who, in turn, should always be responsible to the works manager.

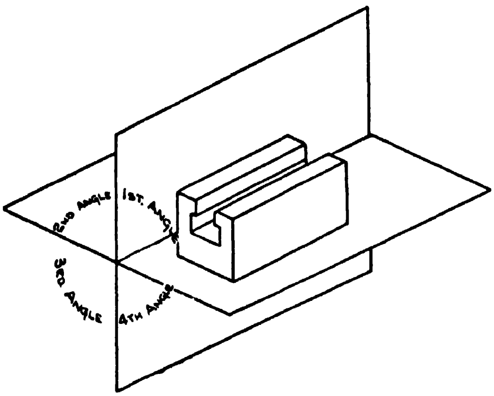


FIG. 240. BRITISH STANDARD FIRST ANGLE PROJECTION—RELATIVE LOCATION OF OBJECT

Drawing Office Standards

Like many other sections of a factory, no two drawing offices appear to be run on identical lines. This is not vital, however, providing that certain standards are followed, and that certain distinctive features characterize the drawings.

Those who have worked in a drawing office may be accustomed to the shop staff advancing more criticism than compliments. If, in consequence, the former develops an attitude of indifference which repels both abuse and helpful criticism, it can only be regarded as a weakness. It is, too, an unfortunate state of affairs if this results in the shop staff thinking that their criticism is disregarded, as much relevant information can come from no other source.

Machine drawing has been well described as "the language of the workshop," for by its aid it is possible to convey to the mind of a skilled craftsman clear and exact information as to the form and dimensions of any object, however complex and intricate, which it is desired to construct.

The British standard practice of using the first angle projection, in which the object to be drawn comes between the observer and the plane of projection, as illustrated in Figs. 240, 241, and 242, should be followed. Thus to project an end elevation looking from the left it should be drawn on the right of the front elevation, and

vice versa. If for any good reason a departure is made, a note stating the direction in which the view is obtained should be included. It is, however, outstandingly important that all the views must be so placed orthographically as to be projected the one from the other so that their mutual connection can be readily traced. In addition to plans and elevations, sectional views must be included wherever necessary to ensure clarity. With sectional views "section" lines, drawn at an angle of 45°, must be inserted, their spacing being dependent on the nature of the object being drawn.

General Characteristics of Drawings

All drawings must be accurate, and since accuracy cannot be obtained without neatness, they must also be neat. Centre lines form an integral part of each view included in the drawing, and should therefore be drawn with great accuracy so as to be perfectly straight and square. In laying down the centre lines some care and judgment are necessary to arrange them so that the spacing between adjacent views may be reasonably uniform, resulting in a well-balanced drawing. Wherever possible the drawing of an object should be made the same size as the object itself.

Clear dimensioning is a first duty, many working drawings, otherwise excellent, being spoiled by poor and badly arranged dimensions. These must always indicate the full size of the object when constructed, no matter what may be the scale of the drawing. The best position should be found for each dimension in order to avoid possible confusion, and whilst the drawing must be fully dimensioned, so that no measurement of the drawing or any calculation is required, no dimension should be repeated on a

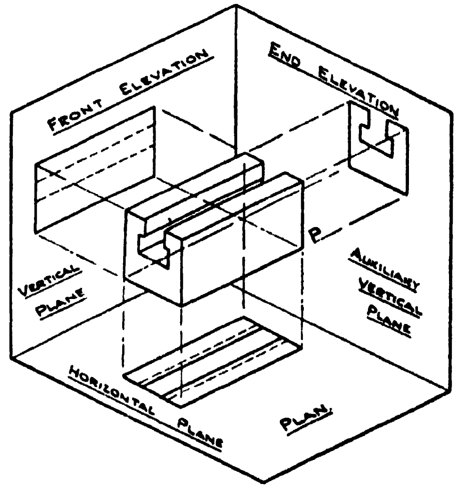


FIG. 241. BRACKET IN THE FIRST ANGLE PROJECTED ON TO THE TWO PRINCIPAL PLANES AND ON TO AN AUXILIARY PLANE MUTUALLY PERPENDICULAR TO THEM

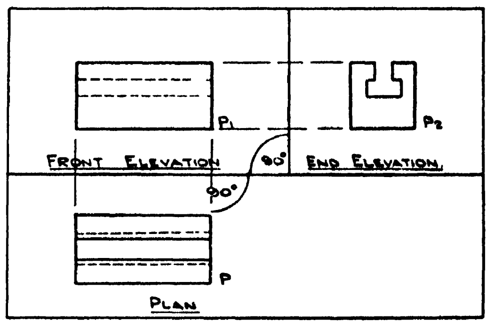


FIG. 242. RELATIVE POSITIONS OF VIEWS CORRESPONDING TO THE ORTHOGRAPHIC PROJECTIONS IN FIG. 241

second view. Diameters should be given on a circle rather than on an elevation, and they should be stated in preference to radii. There should be no repetition of any dimension in different views. Surfaces to be machined should always be clearly

indicated. Such notes as "This dimension is important," "Easy fit," etc., are altogether out of place on a drawing. What is "easy" to the touch of one operator is "tight" to another; the correct procedure is to quote the required tolerance, making it always as great and not as small as the work will allow.

The scale, title, and drawing number should be placed in standard positions, preferably in that order, to the left, centre, and right of the drawing respectively, an inch above the bottom border line. Plain stencilling is much the best method of ensuring uniformity with such information.

A good working drawing leaves nothing of vital importance to the imagination of the craftsman working from it. It is, therefore, necessary to include such explanatory notes and instructions on the drawing as will enable the desired result to be achieved.

Specifications and Codes

The question of identifying a detail on a drawing requires most careful consideration. In the case of composite drawings the simplest method, perhaps, is to give each detail a mark number in the form of a vulgar fraction in which the numerator is the distinctive number of the particular part, and the denominator is the actual drawing number, e.g. $\frac{1}{2468}$ would be detail No. 1 on drawing No. 2468, and $\frac{2}{2468}$ would be detail No. 2 on the same drawing. The mark number may be placed in a circle of one inch diameter, this arrangement giving it emphasis. This practice is not to be confused with the allocation of a manufacturing identification number, to which reference is made in connection with production planning, Chapter XXII.

Where the unit drawing system is adopted the necessity for codes is increased, and these may consist of letters or numbers, or a combination of letters and numbers. The fact that codes are necessary makes their selection of great importance, as subsequent modifications can be seriously confusing. This is particularly so with components when the special tools necessary for their production bear the component code.

As materials have left the simple stage of brass, mild steel or cast iron, material specifications have had to be coded, large numbers of which have been covered by the British Standards Institution. Also, with the advance in interchangeability of components and the consequent transition from fitting and erecting operations to those of assembly, the making of sub-assemblies, or assembly units, has been encouraged, these comprising only a portion of the final product, and requiring yet another code. These codes, initiated in the drawing office, will affect a whole series of subsequent records and activities involving the production planning, tool design, and progress departments, as well as the raw and finished material stores and tool stores.

A more outstanding complication arises when the design for a component is changed after being coded. The only clear method in such cases is to allot a new code, and to see that the

changed code appears on every record concerned. Where drawings are being sent out for the approval of the customer it is suggested that the use of a form such as is shown in Fig. 243 will be helpful. In all cases the working drawing and supplementary records (in the form of manufacturing instructions) should incorporate the greatest help to all departments concerned, and thus make the maximum contribution to the management function.

Unit Drawings versus Composite Drawings

The modern drawing office recognizes that an important function is to facilitate production in accordance with the desired requirements. The working drawing is indeed the advance guard of production management and has been developed to a high state of efficiency. It consequently requires draughtsmen who are conversant with the latest shop practices as well as the plant available. The advent of quantity production for stock and the need for spare parts has popularized the adoption of the unit drawing, which deals with one component only. The advantages and disadvantages of the unit drawing compared with the composite drawing may be summed up as shown on page 304.

It will be seen that the disadvantages of the unit system are not great, whereas the advantages are considerable. If this system is decided upon there are three points which cannot be stressed too strongly—

(1) It is important that high and low limits be given on all drawings.

APPROVAL OF DRAWINGS

CUSTOMER Date

Equipment Ordered Works Order Promised Delivery Date

Title of Drawing	Drawing No	Drawing Sent for Approval						Design Approved by Customer	Change Notice	Remarks
		Issue Letter	Date Sent	Issue Letter	Date Sent	Issue Letter	Date Sent			

FIG. 243. RECORD OF DRAWINGS FOR APPROVAL

Type of Drawing	*Advantages*	*Disadvantages*
Composite	Manufacturing specifications can more easily be drawn up and allied components arranged in strict numerical order, which is highly desirable.	When only one drawing is issued, some inconvenience is caused if more than one operator requires the same drawing at the same time. Records may show that in some cases drawings will be transferred from shop to shop as many as three times in one day.
	A better appreciation is given of finished work requirements.	Several components on one drawing tend to confuse, and many notes which would be helpful are of necessity omitted in order to avoid a mass of detail.
	Drawing sizes can be limited, say six in all, and thus the drawing can be conveniently stored if mounted on rollers.	Such operations as forging and fabrication may be delayed due to items for pattern-making being included on the one drawing.
Unit	Can be easily read, since only one item is shown and any aspect of manufacture is at once apparent.	The draughtsmen's work is increased.
	Each operator is able to proceed with the individual item with which he is concerned, which is a definite advantage from the manufacturing point of view.	There is an increased number of copies for storage and a consequent extension of records.
	In conjunction with production planning the drawings can be considered, handled, issued, and routed in the works as dictated by the method of production decided upon.	Drawings are likely to be small, causing copies to be mislaid. The smallest sizes may not lend themselves to rollers or sticks, and if made larger than necessary will result in much wasted material.
	Date of commencement of work can be controlled with certainty if drawings of details are of unit type.	Additional responsibility is thrown upon the draughtsman with regard to indicating machined surfaces, etc., and the very closest co-operation between the drawing office and the workshops is required.
	The design of jigs, tools, blocks and dies is facilitated before the production of details is commenced.	Reference to general arrangement and sub-assembly arrangements is necessary in order to ascertain the relationship of any one component to another.
	They are more readily prepared and, when necessary, amended in the drawing office.	Necessity for assembly lists and other information to be provided.

(2) It is essential that arrangement drawings be issued simultaneously with the first detail drawings, a procedure which should be insisted upon by the works.

(3) The unit system involves careful preliminary study and a comprehensive survey should be taken so far as the adoption of codes is concerned, especially where gauges, jigs, and tools are identified in accordance therewith.

With regard to (1) the designer often tends to specify closer manufacturing limits than those strictly required for correct performance of the product. For instance, a drawing may carry a general note to the effect that all dimensions, unless otherwise noted, are to be made within plus or minus 0·002 in. A 2-in. fillet joining two surfaces, and which has no other function and does not touch any other surface, may thus be required by an inspector to be made to exactly $2 \pm 0{\cdot}002$ in., although $2 \pm \frac{1}{8}$ in. would make no difference in the

strength or utility of the part. To meet the requirements of the drawing may necessitate hours of machine time on each piece made and thus seriously hamper production. Such a procedure always increases the manufacturing cost and the manufacturing department, which naturally advocates the largest possible tolerances, is often given an unnecessarily heavy if not an impossible task.

Size of Drawings

For the sake of uniformity in the drawing office, as well as in the works, it is desirable that drawings should be kept to definite sizes, perhaps six sufficing, as for example, 18 in. × 12 in., 24 in. × 18 in., 40 in. × 27 in., 40 in. × 30 in., 60 in. × 40 in., and 72 in. × 40 in. Excluding the first two, which can be made up into books, these sizes will permit of standard six-drawer cabinets being provided, each with drawers of five inches depth, and will permit of at least 100 drawings per drawer being accommodated when lying flat.

Reproduction of Drawings

There are several methods of reproduction adopted but, in order of merit, the three principal ones may be stated to be (1) true-to-scale, (2) ferro-prussiate, and (3) dye line. The essential features of these three methods will be described.

True-to-scale. By this method black and white prints are obtained from tracings without bringing the paper into contact with any moisture. The prints are produced first of all by coating a piece of zinc, or a Chalfont table (which is a table with an unbroken piece of lino covering it), with a composition which consists of gelatine and various ferrous salts. The composition is melted down in a water jacket tin and not allowed to exceed 120° F. It is then poured on to the zinc sheet or the Chalfont table and allowed to set, which usually takes about ten minutes in a temperature of about 65° F.

Next a ferro-prussiate print is obtained, on specially prepared ferro paper, which print should be slightly over-exposed. To obtain this the tracing is placed in a cylinder or printing machine with a piece of ferro paper on the back and exposed to a strong light for a few seconds. The print is then rubbed down on to the gelatine and left for a short time, great care being taken that there are no airbells between print and composition. It is next rolled over by a roller charged with greasy printers' ink, the ink adhering to the composition where there are any lines and resisting elsewhere, because the strong light in the printing machine, in passing through the tracing, kills the iron in the paper, and the ink resists that part only. After ascertaining that the lines are well filled with ink by rolling, the prints are taken off by rubbing a piece of white paper on to the composition. The number of prints which can be obtained before the gelatine has to be remelted varies from 15 to 50, but the composition must be inked in before each print is taken off. There is no distortion of the print with true-to-scale printing.

Ferro-prussiate. Ferro-prussiate prints are obtained by placing the

tracing in the printing machine with a piece of ferro paper on the back, exposing to a strong light for a few seconds, and then washing in running water till the lines are white and the ground blue. The prints are then hung up to dry.

Dye Line. These prints are obtained in the same way as ferro-prussiate, then developed either in a special developing machine or rubbed over the surface with a wad of cotton wool dipped in the developer. If the exposure is correct, the print will appear in a few seconds.

If the drawings are intended to be of a permanent character, they should preferably be mounted on linen. In a large firm it will prove economical to keep a full-time staff engaged on reproduction work. In other cases, the services of a local photographic firm which specializes in reproduction work should be called upon as required.

Points in Design

Before leaving the question of drawing office procedure some outstanding features regarding everyday design will be worthy of inclusion.

Accessibility to those details which are likely to require repairs is important. Hand work, which is always costly by comparison with machine work, should be eliminated wherever possible. The instruction "To be marked off in position" should be especially avoided unless it is really necessary, as this often means extra work and, of course, adversely affects interchangeability. Lack of adequate room for a spanner-hold is not infrequent—a quarter of an inch too much is far more acceptable than an eighth of an inch too little. Drilling is worthy of attention. Variations in diameter should be kept down to a reasonable number, and in designing studs and screws sixteenths of an inch should not be used above half an inch diameter. The drilling of long holes and blind tapped holes absorbs a lot of time, and therefore costs money. The inclusion of taper pins should not be overdone. Without doubt a well-fitted taper pin is a good job, but very often it is a better job than is required. One has only to analyse the fitter's time to find that a taper pin can be several times as costly as a screw or bolt. Where changes in section occur there should always be as large a radius as is practicable, otherwise fractures can be expected.

Suggested alterations to design, from whatever source they may emanate, should not be adopted if the cost is increased without a corresponding improvement in efficiency. For instance, it is unsound to fit needle roller bearings if plain bearings are adequate, or to use a special alloy steel instead of a malleable casting, or to introduce a complicated casting instead of a simple fabricated component. It is, of course, essential that the objections raised to such a course are always logically sound.

Alterations to a drawing should be clearly shown, and their nature briefly referred to, together with the date of alteration, in a column previously provided for the purpose. Alternatively a new drawing, with a new number, should be issued.

The recalling of a drawing for

alteration after its having once been issued is generally a costly business and has nothing in its favour. The inconvenience in the production planning office is considerable because it means the cancellation of operation sheets, material requisitions and wages tickets which have already been issued, and a fresh start being made. In the works it may mean the cancellation of jigs and tools, and the scrapping of a number of expensive components with no compensation.

The Works Drawing Stores

Although the drawing stores is not so prominent as some sections of the works it is one which will cause endless trouble if it is not placed on a sound footing.

One full-time drawing storekeeper for dealing with shop drawings should fully meet the requirements of a large works. His principal duties will be: (1) to maintain a register of all new shop drawings issued in the works, (2) to arrange for shop drawings to be mounted and maintained in good condition, (3) to ensure that each shop concerned is notified when a new drawing is issued, or when one has been altered, and (4) to keep a record of the whereabouts of every shop drawing.

The first-mentioned is best done by the use of a foolscap book in which the drawings are entered in numerical order and the title stated. With regard to the second, unless there are very good reasons for arranging otherwise, there should be only one shop copy issued of any drawing. If it is to be in use for any length of time it should be a linen copy mounted at the left-hand side on a stick which is, say, of 1 in. diameter and 6 in. longer than the width of the drawing, on which projection a "flat" is made for insertion of the drawing number. A flat stick, the width of the drawing and of, say, 1 in. × $\frac{3}{8}$ in. section, fixed to the right-hand side of the drawing, with a short tape tied to the middle of the stick, will permit of the drawing being kept in a satisfactory rolled-up condition. This is an effective method of mounting which can be carried out by an apprentice at a cost of a few pence per drawing, and is ideally economical so far as storage room is concerned, whether in the drawing stores or on racks provided at certain points in the shops.

For the purpose of the third duty, the production planning office should issue sufficient copies of the form shown in Fig. 244 to provide one for each office and shop concerned, as well as two additional copies. One of these latter should be signed by the works manager and returned to the drawing office, thus acknowledging that the drawing has been received in the works. The other copy should be taken by the drawing storekeeper to each shop and he will obtain a signature on this copy from a responsible person when he hands over their own copy of the form. The drawing storekeeper should eventually file his copy, which should include a signature from every section concerned in the works.

The fourth duty can best be achieved by a card index system, one card being used for each drawing. A sample of the card required is illustrated in Fig. 245, the reverse side being printed similarly, except that

DRAWINGS FOR WORKS ORDER NO. DATE

The undermentioned Prints have been Issued on the Works this day, and will require attention in the Depts. and Shops marked X.

Print No.	Abbreviations	TITLE (Give full particulars of miscellaneous details shown on prints)	Assembly	Central Stores	Coppersmiths	Drg. Stores	Erection	Finishing	Fitting	Forge	Machine	Millwrights	Pattern	Planning	Smiths	Stamping	Tinsmiths	Welding

Key to Abbreviations:
- S = Standard
- N = Issued 1st time.
- A = Altered.
- R = Replaced
- C = Cancelled

Signed

FIG 244 FORM SHOWING ISSUE OF DRAWINGS

DRG NO

TITLE

Date Issued	Shop	Date Returned	Date Issued	Shop	Date Returned	Date Issued	Shop	Date Returned

FIG 245 CARD FOR INDEXING SHOP DRAWINGS

the heading is not repeated. It will be seen that an appropriate entry is made every time the drawing is borrowed. The shop drawing requisition, of which a sample is shown in Fig. 246, should be filed with the card by means of a slip-on fastener.

If a second requisition is presented for the same drawing by another shop, the first requisition should

REQUISITION FOR DRAWING

Shop

Date

To Drawing Storekeeper

Please Issue to Bearer

Drawing No.

Title

(Signed)

Fig 246 Shop Drawing Requisition

be handed by the drawing storekeeper to the second shop's representative, which will represent the latter's authority for obtaining the drawing from the shop already in possession. The second shop's requisition should now be filed with the index card. In the event of the first shop not releasing the drawing as anticipated, the first requisition should be returned to the drawing stores and the second one reclaimed. When a drawing is returned to the stores, the requisition should be stamped "Cancelled" and handed back to the shop representative. The whole system is extremely simple in operation, and at the same time thoroughly efficient.

Initiation of Manufacture

Apart from the initial order, an example of which is given in Chapter XXII, Fig. 265, manufacturing instructions usually take the form of particularized instructions regarding aspects of production not made sufficiently explicit by the working drawings or other records issued by the drawing office. Manufacturing instructions may be wholly in terms of the customer's specification, requiring interpretation in the form of working drawings, etc., by the drawing office, or alternatively they may be quantity authorizations for production to designs and specifications evolved by the development department and completed by the drawing office.

Manufacturing instructions are a convenient channel for conveying to processing departments instructions that are either too general to be effective on a drawing or assembly list, or would not be sufficiently emphasized if circulated in that way.

CHAPTER XXI

ESTIMATING

Use of Estimates

ESTIMATING is generally carried out for either of two quite different reasons. In the one case it is done to provide a basis when tendering for work which differs from work performed previously, or for similar work previously manufactured differently; in the other it is done to prepare information which will indicate to the directorate whether or not a proposed reorganization or extension scheme within the factory is likely to prove financially and economically sound.

Estimating is unquestionably the work of a specialist, as neither practical skill in defining operations, nor the manner in which available data can be applied, is a substitute for a natural ability to read drawings and to assess a value for the material and labour involved. Success in this department may be the key to the success of the business as a whole. It is suggested that in the average factory where the total staff is in the thousands the works estimating office will require for its successful running a staff comprising either two or three intelligent technicians and one clerk.

The estimating office is an essential part of the works organization and, if the policy is sound the technicians, who should have at least completed a full apprenticeship in the works, will be in almost daily contact with the drawing office, the purchasing department, the shop supervisory staff, and the rate-fixers, thus ensuring the closest co-operation and the most economical manufacturing cost or layout. It is not improbable that their duties will also require them to estimate delivery conditions, including penalties for late delivery, as well as to allow for contingencies due to defective work and inspection requirements of the customer, and to overtime and night shift working. Insurance premiums and terms of payment are further items which will affect the ultimate price to be quoted. Generally the actual costs of previous work, when compared with the manufacturing estimate, will provide a basis for applying a suitable percentage to the works or departmental cost, according to the nature of the liability.

Preparation of Manufacturing Estimates

The preparation of a manufacturing estimate will proceed along one of two channels after the drawings have been scrutinized.

(1) By the extraction from existing records of items which have been dealt with under previous manufacturing estimates, or which are covered by the stores department stock. In the latter case, actual costs should be available from the accountant by reference to his cost record of stock items manufactured in the works. A card record (Fig. 247) printed on both sides is

Standard Weight		Class	Catalogue	Unit

RECEIPT RATE

Date	Rate	Date	Rate	Date	Rate	Date	Rate

ISSUING RATE

FIG 247 COST RECORD OF STOCK ITEMS

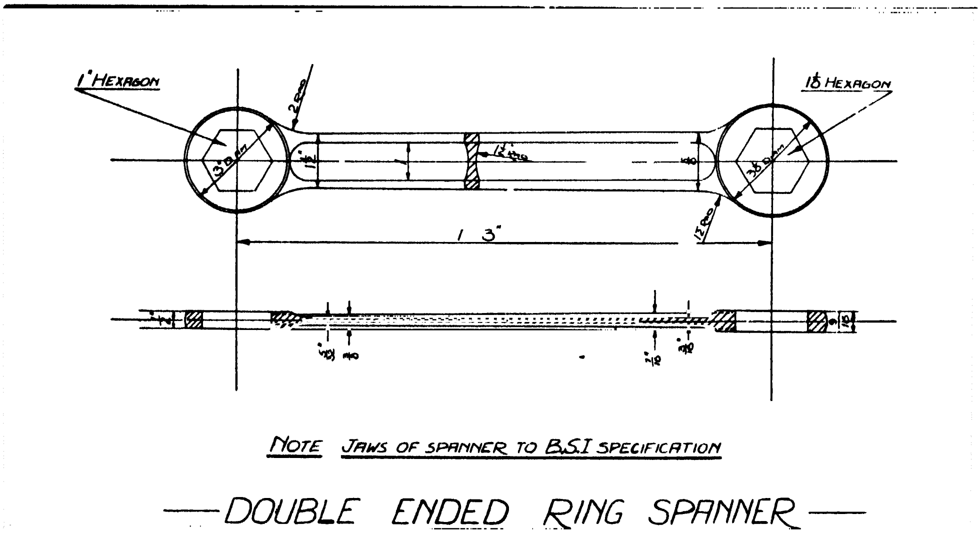


FIG 248 DOUBLE ENDED SPANNER

recommended for this purpose. The remaining details required, and assembly operations which may be necessary, will then be estimated and set out on the appropriate forms.

(2) For items which are not available the estimating office will require to build up the complete estimate. In conjunction with the production planning staff they should decide on the shops which they consider are the most favourably equipped for the particular work to be done, and should ascertain the grades of operators concerned and the sequence of every operation involved, and, from the rate-fixers if necessary, the anticipated basis time or piecework rates to be paid for such grades and operations. This detailed procedure has the added advantage of verifying at the outset that every requirement can be met by the plant and equipment available, or alternatively that some details or work will require to be sub-contracted on other manufacturers.

It will be helpful to consider some examples in detail.

Example No. 1. It is required to estimate for the manufacture of 1000 double-ended spanners of the type shown in Fig. 248. A technician should calculate the rough and finished weights and submit the whole of the information which he has obtained to the works costs accountant on a Material and Operation Schedule form, Fig. 249. The average number of operations per detail will probably only be from six to eight; if more, it will necessitate additional sheets to compile the estimate. The works costs accountant should then convert the information supplied to him into £ s. d. and submit the completed estimate on a Manufacturing Costs Schedule form, Fig. 250. These sample forms provide considerable relevant information and should be closely studied by all who are required to furnish manufacturing estimates.

Example No. 2. It is required to estimate for the manufacture of 600 $1\frac{1}{2}$ in. brass stop valves of the type shown in Fig. 251. The calculations involved in obtaining the weight of material required are shown in Figs. 252 and 253. The quantity of machinings is ascertained by taking a percentage of the finished weight according to the design of the detail concerned (in this case 40 per cent). So far as the runners are concerned experience may reveal that with this class of work the weight of runners per moulding plate varies between 4 and 6 lb. In this case therefore 5 lb. per plate for the body or plug has been assumed.

The next stage is to prepare, as in the previous example, the Material and Operation Schedule, Fig. 254, and for the works costs accountant to use this in preparing his Manufacturing Costs Schedule, Fig. 255. Separate forms will be required for each detail, the examples given (Figs. 254 and 255) referring only to the body. When all the forms are complete a summary of the estimated cost, Fig. 256, should be compiled.

Whilst the foregoing are only straightforward examples, they typify the exact procedure to be followed in work of a more involved character, the only difference being that more

MANUFACTURING COSTS
MATERIAL AND OPERATION SCHEDULE

Date *2nd January, 1940*

Detail 1 in. × $1\frac{1}{8}$ in. *Double-ended Spanner* Mark No. *1/1368* ESTIMATE No. *326*

For *General Use* Drg. No. *1368*

Order No. *1340* Catalogue No. *16/5006*

Economical Manufacturing Quantity: *100.* Anticipated Ordering Quantity: *1000.*

MATERIAL

	Description	Spec. and Grade	Length Ordered	Length Per Detail	Catalogue No.
A B C	*Steel Bar, 2 in. dia.*	*BSS 5005/101*	*Commercial*	*9 in.*	*13/8850*

WEIGHTS

	Rough			Scrap Bloom			Scrap Runners			Net			Machinings			Finished			Per
	C.	Q.	Lb.	C.	Q.	Lb.	C.	Q.	Lb.	C.	Q.	Lb.	C.	Q.	Lb.	C.	Q.	Lb.	
A B C	–	–	*8*	–	–	$3\frac{1}{2}$	–	–		–	–	$4\frac{1}{2}$		–	$\frac{1}{2}$	–	–	*4*	*Each*

OPERATIONS

Op. No.	Operations in Detail	Shop and Group	Ident. No.	P.W.P. s. d.	Per
1	*Setting Die Blocks*	*Forge/5*	*1500*	*6 0*	*100*
2	*Drop Stamping*	*Forge/5*	*1670*	*4*	*Each*
3	*Dressing*	*Fitting/20*	*2123*	*3*	*Each*
4	*Hardening*	*Heat treatment*	*7231*	*1*	*Each*

OPERATIONS WHICH ARE NOT A DIRECT CHARGE *Nil* .

MACHINES AND LABOUR

Op. No.	Type of Machine	Grade of Labour	Base Rate	Bonus % Earned
1	*30 cwt. Drop Hammer* . .	*Drop Stamper* . .	*56s.*	*42*
		Furnaceman . . .	*46s.*	*42*
		Hammer Driver . .	*44s.*	*42*
2	*30 cwt. Drop Hammer* . .	*Drop Stamper* . .	*56s.*	*42*
		Furnaceman . . .	*46s.*	*42*
		Hammer Driver . .	*44s.*	*42*
		Apprentice . . .	*21s.*	*35*
		Tool Hardener . .	*52s.*	*37*

Tooling Equipment { Available
Required *Drop Stamp Die Blocks at estimated cost of £10*

Workshop Expenses for period *September, 1939* to be used for this Estimate.

FIG. 249. MATERIAL AND OPERATION SCHEDULE FORM FOR DOUBLE-ENDED SPANNER

MANUFACTURING COSTS
COST SCHEDULE

Date *3rd January, 1940*

Detail 1 in. × $1\frac{1}{8}$ in. *Double-ended Spanner* Mark No. *1/1368* Estimate No. *326*

For .. *General Use* Drg. No. *1368*

Order No. *1340* Catalogue No. *16/5006*

Economical Manufacturing Quantity: *100.* Anticipated Ordering Quantity: *1000.*

Variable Cost

(1) Material

	Description	Rough Wt. C. Q. Lb.	Rate *per ton*	Cost per *100* £ s. d.	Cost Each £ s. d.
A B C	*Steel Bar, 2 in. dia.*	*8 each*	*£10 10s.*	*3 15 0*	*9·0*
	Credit for Recovered Scrap —				
	Bloom	*3¼*	*£3*	*9 4 5*	*1·1*
	Machinings	*½*	*£2 10s.*	*1 1·5*	*0·1*
	Net Material Cost . .			*3 4 6·0*	*7·7*

(2) Wages

Op. No.	Operation	P.W.P.	Per	Rate of Operator	Workshop Expense % Applicable V.	N.V.	Cost per *100* £ s. d.	Cost Each £ s. d.
1	*Setting Die Blocks* . .	*6s.*	*100 Spanners*	*56s., 46s., 44s.*	*75*	*25*	*6 0 0*	*0·7*
2	*Drop Stamping* . .	*4d.*	*Spanner*	*56s., 46s., 11s.*	*75*	*25*	*1 13 4 0*	*4·0*
3	*Dressing*	*3d.*	*do.*	*21s.*	*10*	*30*	*1 5 0 0*	*3 0*
4	*Hardening* . .	*1d.*	*do.*	*52s.*	*20*	*30*	*8 4·0*	*1·0*
	Total Wages Cost						*3 12 8·0*	*8·7*

	Cost per *100* £ s. d.	Cost Each £ s. d.
(3) Overhead Charges		
(*a*) Workshop Expenses (Variable Proportion) . . .	*1 13 8·0*	*4·0*
(*b*) Incidental Charges (Do.)	*11 9·6*	*1·4*
(*c*) Add Workmen's Insurance and Compensation	*2 6 5*	*0·3*
(V) Total Variable Cost	*9 5 2·1*	*1 10·1*
Non-variable Cost		
(4) Overhead Charges		
(*d*) Workshop Expenses (N.V. Proportion)	*19 10 0*	*2 4*
(*e*) Incidental Charges (Do.)	*3 11·2*	*0·5*
(*f*) Works Superintendence Charges	*5 5·4*	*0·7*
(N) Total Non-variable Cost . .	*1 9 2·6*	*3·6*
Total Works Cost (V + N)	*10 14 4·7*	*2 1·7*
(5) Add: (*a*) Percentage Allowance for *Selling Costs, 5%*	*10 8·6*	*1·3*
(*b*) Do. *Carriage, say 100 miles @ £2 per ton* .	*7 1·7*	*0·9*
(*c*) Do.		
(6) Total Cost Excluding Profit	*11 12 3 0*	*2 3·9*
Add *20* per cent for Profit	*2 6 5·4*	*5·6*
(7) Overall Cost	*£13 18 8·4*	*2 9·5*

Material Rates and Workshop Expenses for Period *September, 1939* used for Cost.

Estimated Expenditure on Dies, etc. *Drop Stamp Die Blocks, £10*

Fig. 250. Manufacturing Costs Schedule Form for Double-ended Spanner

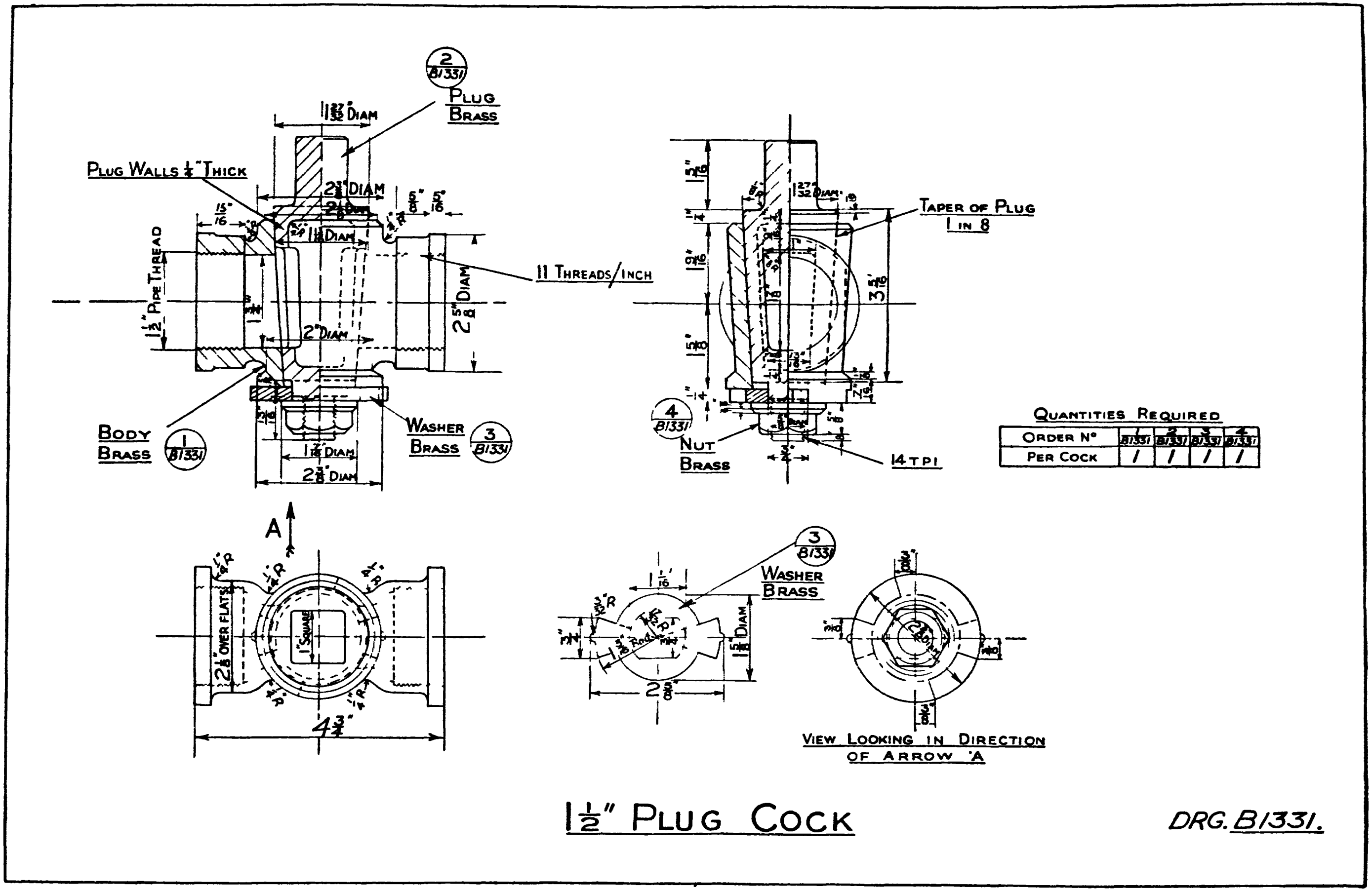


Fig. 251. $1\frac{1}{2}$ in. Brass Stop Valve

ESTIMATE No. 105

$1\frac{1}{2}$ in. Stop Cock. Material: Brass

ESTIMATED WEIGHTS FOR PURPOSE OF COMPILING ESTIMATE

Body (Finished Weight)

Assume volume of square equals volume of port.

Volume = Two hollow cylinders. One $2\frac{1}{4}$ in. outside dia., $1\frac{7}{8}$ in. inside dia., and 3 in. long; and one $2\frac{1}{8}$ in. outside dia., $1\frac{9}{16}$ in. inside dia., and $3\frac{1}{2}$ in. long; less the area of the two ports (i.e. two rectangular sections $1\frac{3}{4}$ in. × $\frac{7}{8}$ in. × $\frac{1}{4}$ in. thick).

= (3·976 sq. in. − 2·761 sq. in.) 3 in. + (3·547 sq. in. − 1·918 sq. in.) $3\frac{1}{2}$ in. − 2($1\frac{3}{4}$ in. × $\frac{7}{8}$ in. × $\frac{1}{4}$ in.)

= 3·645 + 5·702 − 0·765 = 8·582 cub. in.

∴ Weight = 8·582 cub. in. × 0·3 lb. (Note: 1 cub. in. of brass weighs 0·3 lb.)

= 2·575 lb. = *2 lb. 9 oz.*

Plug (Finished Weight)

Volume = Cylinder of diameter equal to mean dia. of frustrum of cone, i.e. $1\frac{5}{8}$ in. dia. multiplied by length, i.e. $2\frac{1}{4}$ in.

= (Area of circle $1\frac{5}{8}$ in. dia.) × $2\frac{1}{4}$ in. = 2 sq. in. × $2\frac{1}{4}$ in. = $4\frac{1}{2}$ cub. in.

∴ Weight = 4·5 × 0·3 lb. = 1·35 lb. = *1 lb. $5\frac{1}{2}$ oz.*

Washer (Finished Weight)

Volume = Cylinder $1\frac{1}{2}$ in. dia., $\frac{1}{4}$ in. long.

= 1·767 sq. in. × $\frac{1}{4}$ in. = 0·442 cub. in

∴ Weight = 0·442 × 0·3 × 16 oz. = *2·1 oz.*

Nut (Finished Weight)

Volume = Hollow cylinder $1\frac{1}{4}$ in. outside dia., $\frac{5}{8}$ in. inside dia., $\frac{5}{8}$ in. long.

= (1·227 sq. in. − 0·307 sq. in.) × 0·625 in. = 0·575 cub. in.

∴ Weight = 0·575 × 0·3 × 16 oz. = *2·76 oz.*

(Note: After ascertaining the finished weight it is necessary to calculate the weight of runners and machinings. In this instance a knowledge of the usual allowances for the particular class of article has been assumed. Sometimes, however, a more detailed calculation will be necessary.)

FIG. 252. CALCULATION OF WEIGHT OF $1\frac{1}{2}$ IN. BRASS STOP VALVE

ESTIMATE No. 105

SUMMARY OF ESTIMATED WEIGHTS FOR PURPOSE OF COMPILING ESTIMATE

$1\frac{1}{2}$ in. Stop Cock. Material: Brass

Detail	Finished Weight Each	Per 20 Stop Cocks			No. of Patterns per Plate	Per 20 Stop Cocks	
		Finished Weight	Machinings Weight	Net Weight (B + C)		Runners Weight	Rough Weight (D + F)
	(A) lb. oz.	(B) lb. oz.	(C) lb. oz.	(D) lb. oz.	(E)	(F) lb. oz.	(G) lb. oz.
Body . .	2 9	51 4	20 8	71 12	4	25 0	96 12
Plug . .	1 5·5	26 14	10 12	37 10	6	25 0	62 10
Washer . .	2·1	2 10	17	3 11	24	2 8	6 3
Nut . .	2·76	3 7	5·5	3 12·5		--	3 12·5

FIG. 253. WEIGHT SUMMARY OF DETAILS FOR $1\frac{1}{2}$ IN. BRASS STOP VALVE

MANUFACTURING COSTS
MATERIAL AND OPERATION SCHEDULE

Date *2nd January, 1940*

Detail... *Body*
For *1½ in. Stop Cock*
Order No. *1212*
Economical Manufacturing Quantity: *20.*

Mark No. *1/1331* ESTIMATE No. *105*
Drg. No. *B/1331*
Catalogue No. *8/54131*
Anticipated Ordering Quantity: *600.*

MATERIAL

	Description	Spec. and Grade	Length Ordered	Length Per Detail	Catalogue No.
A B C	*Brass Alloy A.1*	*Cu = 87%. Zn = 2%* *Sn 9%. Pb = 2%*	—	—	—

WEIGHTS

	Rough	Scrap: Bloom	Scrap: Runners	Net	Machinings	Finished	Per
	C. Q. Lb.	C. Q. Lb.	C. Q. Lb.	C. Q. Lb.	C. Q. Lb.	C. Q. Lb.	
A B C	3 16¼	—	25	2 19¼	21½	1 25¾	20

OPERATIONS

Op. No.	Operations in Detail	Shop and Group	Ident. No.	Basis Time H. M.	Per
1	*Coremaking*	*Foundry/3*	*654*	*5 0*	*20*
2	*Machine Moulding (4 per Plate)*	*Foundry/2*	*2560*	*2 45*	*20*
3	*Fettling*	*Foundry/5*	*1, 2, and 3*	*40 0*	*ton*
4	*Turning, Boring, and Thread Cutting*	*Machine/14*	*37512*	*25 0*	*20*
5	*Milling two Hexagons*	*Machine/15*	*38163*	*5 20*	*10*

OPERATIONS WHICH ARE NOT A DIRECT CHARGE ... *Nil* ..

MACHINES AND LABOUR

Op. No.	Type of Machine	Grade of Labour	Base Rate	Bonus % Earned
1	——	*Apprentice*	*16s.*	*49*
2	*Moulding*	*Machine Moulder*	*47s.*	*43*
3	*Sandblasting and Grinding*	*Fettler*	*48s.*	*45*
4	*Turret Lathe*	*Turner*	*56s.*	*38*
5	*Milling*	*Apprentice*	*14s.*	*40*

Tooling Equipment {Available *Machine Tools*
{Required *Patterns at an estimated cost of £6*

Workshop Expenses for Period *September 1939* to be used for this Estimate.

FIG. 254. MATERIAL AND OPERATION SCHEDULE FOR 1½ IN. BRASS STOP VALVE

MANUFACTURING COSTS
COST SCHEDULE

Date *3rd January, 1940*

Detail... *Body*	Mark No. *1/1331* ESTIMATE No. *105*
For *1½ in. Stop Cock*	Drg No. *B/1331*
Order No. *1212*	Catalogue No *8/54131*
Economical Manufacturing Quantity: *20.*	Anticipated Ordering Quantity: *600.*

VARIABLE COST

(1) MATERIAL

	Description	Rough Wt C Q Lb	Rate per Cwt	Cost PER 20 £ s d	Cost Each £ s. d.
A B C	*Brass Alloy, A.1*	*3 16½* *per 20*	*45s*	*2 0 3 5*	*2 0 2*
	Credit for Recovered Scrap —				
	Runners	*25*	*1s 6d*	*9 5 7*	*5 7*
	Machinings	*21½*	*40s*	*7 8 0*	*4 6*
	NET MATERIAL COST			*1 3 1 8*	*1 1 9*

(2) WAGES

Op No	Operation	Basis Time h m	Per	Rate of Operator	Workshop Expense % Applicable V	N.V	Cost PER 20 £ s d	Cost Each £ s. d.
1	*Coremaking*	*5 0*	*20*	*16s*	*65*	*30*	*10 4*	*0 5*
2	*Machine Moulding*	*2 45*	*20*	*47s*	*75*	*30*	*1 8 8*	*1 0*
3	*Fettling*	*40 0*	*Ton*	*48s*	*35*	*20*	*9 0*	*0 4*
4	*Turning*	*25 0*	*20*	*56s*	*25*	*35*	*18 5 6*	*11 1*
5	*Milling*	*5 20*	*10*	*14s*	*25*	*35*	*1 10 8*	*1 1*
	TOTAL WAGES COST						*1 3 8 6*	*1 2 1*

	Cost PER 20 £ s d	Cost Each £ s. d.
(3) OVERHEAD CHARGES		
(*a*) Workshop Expenses (Variable Proportion)	*7 2 7*	*4 3*
(*b*) Incidental Charges (Do.)	*1 9 5*	*1 1*
(*c*) Add Workmen's Insurance and Compensation	*10 0*	*0·6*
(V) TOTAL VARIABLE COST	*2 16 8 6*	*2 9 9*
NON-VARIABLE COST		
(4) OVERHEAD CHARGES		
(*d*) Workshop Expenses (N V. Proportion	*8 0 2*	*4 8*
(*e*) Incidental Charges (Do)	*10 7*	*0 6*
(*f*) Works Superintendence Charges	*1 9 3*	*1 1*
(N) TOTAL NON-VARIABLE COST	*10 8 2*	*6 4*
TOTAL WORKS COST (V + N)	*3 7 4 8*	*3 4 3*
(5) Add: (*a*) Percentage Allowance for *Selling Costs, 5 per cent*	*3 4 4*	*2 0*
(*b*) Do. *Carriage, say 100 miles @ £2 per ton*	*11 0*	*0 6*
(*c*) Do.		
(6) TOTAL COST EXCLUDING PROFIT	*3 11 8 2*	*3 6 8*
Add *20* per cent for Profit	*14 4 0*	*8 6*
(7) OVERALL COST	*£4 6 0 2*	*4 3 4*

Material Rates and Workshop Expenses for Period *September 1939* used for Cost.

Estimated Expenditure on Dies, etc : *Patterns, £6*

FIG. 255. MANUFACTURING COSTS SCHEDULE FOR 1½ IN. BRASS STOP VALVE

copies of the printed forms of the two types shown will require to be filled up in order that a summary of the estimated cost of a complete unit can be ascertained.

With some firms, more especially the smaller ones, it may prove expedient for the material and operation schedule and the manufacturing costs schedule to be telescoped into one form. Whether or not this is done, there will be times when an approximation may be safely made resulting in some of the detailed work being curtailed. Certainly, however, the more detailed and systematic the estimating, the greater will be the help provided for operation planning. With large contracts it is always advisable to add a reasonable percentage for contingencies.

3rd January, 1940

SUMMARY OF ESTIMATE No. 105

*Stop Cock: 1½ in. Drawing No. B.*1331

Detail	Material	Direct Wages	Variable Cost	Non-variable Cost	Works Cost	Overall Cost
	s. d.	*s. d.*	*s. d.*	*s. d.*	*s. d.*	*s. d.*
Body	1 1·9	1 2·1	2 9·9	6·4	3 4·3	4 3·4
Plug	7·3	9·1	1 10·1	4·2	2 2·3	2 9·4
Washer	0·8	1·4	3·4	0·6	4·0	5·1
Nut	1·8	0·5	1·2	0·3	1·5	1·9
Assembly of Cock	—	5·4	6·6	1·2	7·8	10·7
	1 11·8	2 6·5	5 7·2	1 0·7	6 7·9	8 6·5

(Patterns not included)

FIG. 256. SUMMARY OF ESTIMATED COST OF 1½ IN. BRASS STOP VALVE

Influencing the Design

Sometimes a cheaper method of manufacture, without any loss in the efficiency of the article, suggests itself to the works. A casting may be suggested instead of a forging, a fabricated unit instead of a casting or forging, or sometimes vice versa. There is no hard and fast rule—each case must be taken on its merits, the quantity ordered and the patterns, jigs, special tools, and gauges required all having to be taken into consideration. The procedure which must be followed is really a form of job analysis.

Where a genuine saving can be effected, the drawing office should be advised and a request made for the design to be modified to suit. No such change should, of course, be made unless the drawing office is in agreement and confirms its approval by promptly altering the drawing or drawings concerned.

Alternative Methods of Manufacture

There will be many other cases, apart from those mentioned, where an alternative method of manufacture will present itself without in any way affecting the design or the material. Consider the case of the pipe flange, Fig. 257. Assume that it has previously been manufactured as a drop

stamping, but that the time has arrived when new stamping dies at an estimated cost of £8 are required. The question is consequently raised as to whether this is the cheapest method of manufacture, or whether by burning out of a flat steel plate by oxy-

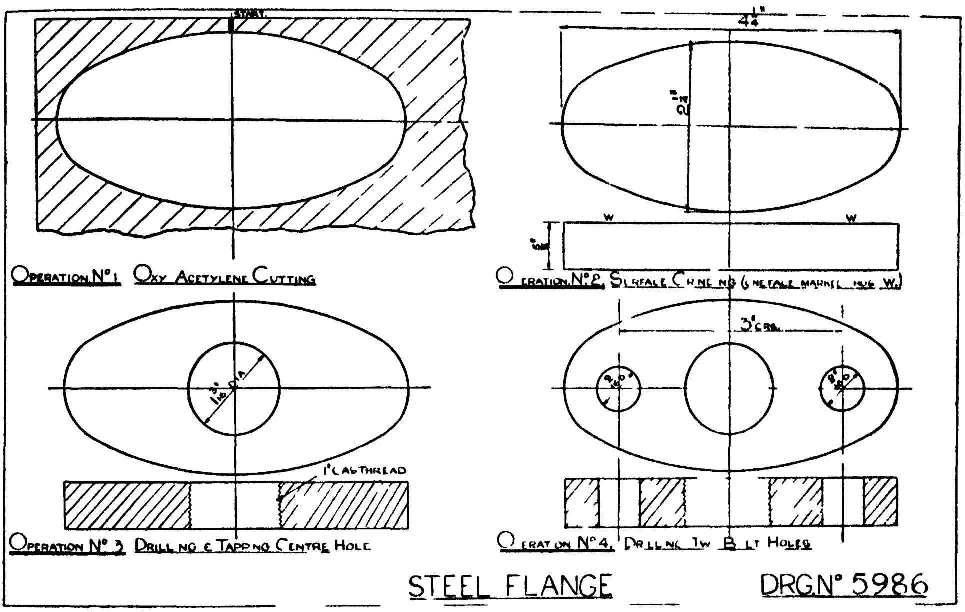


FIG. 257 PIPE FLANGE

acetylene or oxy-coal gas the flange will be less costly. In such cases the usual estimates will be prepared, and when this has been done a comparison should be made on the lines suggested in Fig. 258. It will be seen that the cost by drop stamping is 1s 3d, and by burning out is $7\frac{1}{2}$d The influence of the workshop expense charges should be carefully noted, i.e., drop stamping 200 per cent, acetylene cutting 68 per cent. The comparison reveals, therefore, that the second method has everything to commend it.

Factors Influencing Wages Cost

Not infrequently the base rate of an operator is supplemented by a "cost of living" bonus, which by agreement with the trades unions varies from time to time according to the economic situation of the country. This bonus must not be confused with premium bonus hours or piecework balance, a full explanation of which has been given in Chapter XIX If an operator works on a night shift, or works overtime, for which period he receives an enhanced rate, say of time-and-a-third, a third of the base rate will be added after the piecework balance has been computed from the actual hours worked. Similarly, a third will also be added to the "cost of living" bonus

Consider an example. In order to

25th July, 1940

ANALYSIS OF MANUFACTURING COST

Item	Pipe Flange	Estimate No.	232
Drawing No.	5986	Mark No..	2/5986
Catalogue No.	16/13512		

PARTICULARS OF ESTIMATE
(*Equated to* 1 *Pipe Flange*)

Present Method	*s.*	*d.*	*Proposed Method*	*s.*	*d.*
Material Cost		1·79	Material Cost		1·24
Wages Cost		4·00	Wages Cost		3·00
Variable Cost		10·93	Variable Cost		5·15
Non-variable Cost		4·12	Non-variable Cost		2·09
Works Cost	1	3·05	Works Cost		7·24
Overall Cost	1	6·06	Overall Cost		8·69

MATERIAL AND WEIGHTS

Steel Bar: $1\frac{5}{8}$ in. diameter.
Tensile Strength: 28 to 33 tons per sq. in.
Catalogue No. 13/8290.

	lb.	*Rate per Ton* £	*s.*	*d.*
Rough Weight . . .	1·60	11	6	8
Less Scrap Bloom . .	0·25	1	12	6
Less Machinings . . .	0·35	2	5	0
Finished Weight . .	1·00			

Steel Plate: $\frac{5}{8}$ in. thick.
Tensile Strength: 28 to 32 tons per sq. in.
Catalogue No. 13/25720.

	lb.	*Rate per Ton* £	*s.*	*d.*
Rough Weight . . .	2·12	7	3	8
Less Scrap Plate . . .	0·81	3	13	6
Less Machinings . . .	0·31	2	5	0
Finished Weight . . .	1·00			

OPERATIONS, P.W.P. AND OPERATORS' RATES

Operation	*P.W.P.* *s.*	*d.*	*W.E.* %	*Per*	*Operators' Rate*
Drop Stamping .	8	4	200	50	52s. and 42s.
Drilling, Tapping, and Countersinking .	6	3	80	50	50s.
Surface Grinding .	2	1	40	50	52s.

Operation	*P.W.P.* *s.*	*d.*	*W.E.* %	*Per*	*Operators' Rate*
Oxy-acetylene Cutting by Machine . .	4	2	68	50	56s.
Drilling, Tapping, and Countersinking .	6	3	80	50	50s.
Surface Grinding .	2	1	40	50	52s.

TOOLING EQUIPMENT

Drop Stamping Die Blocks reported for renewal. Cost: £8.	On Hand.

FIG. 258. COMPARISON OF TWO METHODS OF MANUFACTURE OF PIPE FLANGE

fulfil a certain contract a factory proposes to work its productive staff in two shifts—on days from 8.0 a.m. to 8.0 p.m., and on nights from 8.0 p.m. to 8.0 a.m., with 1 hour meal break on each shift.

The following figures will thus probably obtain—

Day Shift

	Rate of Pay	Actual Working Time H. M.	Overtime Allowance H. M.
8 0 a.m. to 5.30 p.m. . (Allowing 1 hour break)	Normal	8 30	—
5 30 p.m. to 7.30 p.m.	Time and a quarter	2 0	30
7 30 p m. to 8.0 p.m .	Time and a half	30	15
		11 0	45
	Premium Bonus (assuming 50%)	5 30	–
	TOTAL	16 30	45

Let R = Base Rate per hour in pence,

and C = Cost of Living Bonus per hour in pence.

Then increase in Wages Cost

$$= \frac{\frac{3}{4}R + \frac{3}{4}C}{16{\cdot}5R + 11C}$$

Assuming an average base rate of 40s. and a cost of living bonus of 20s., for a 47-hour week, using the above nomenclature we get the following—

$$\frac{\frac{3}{4} \times 10 + \frac{3}{4} \times 5}{16{\cdot}5 \times 10 + 11 \times 5} = \frac{7\frac{1}{2} + 3\frac{3}{4}}{165 + 55} = \frac{11{\cdot}25}{220}$$

$$= 5{\cdot}0 \text{ per cent.}$$

Night Shift

	Rate of Pay	Actual Working Time H M	Overtime Allowance H M
8 0 p.m. to 6 0 a.m (Allowing 1 hour break)	Time and a third	9 0	3 0
6 0 a.m. to 8 0 a m.	Time and a half	2 0	1 0
		11 0	4 0
	Premium Bonus (assuming 50%)	5 30	—
	TOTAL .	16 30	4 0

∴ Assuming a base rate and cost of living bonus as above for a 47-hour week, the increase in wages cost is equal to—

$$\frac{4R + 4C}{16{\cdot}5R + 11C} = \frac{4 \times 10 + 4 \times 5}{16{\cdot}5 \times 10 + 11 \times 5}$$

$$= \frac{40 + 20}{165 + 55} = \frac{60}{220} = 27{\cdot}0 \text{ per cent.}$$

∴ As both shifts are of equal length the average increase over the ordinary rate equals—

$$\frac{5{\cdot}0 \text{ per cent} + 27{\cdot}0 \text{ per cent}}{2} = 16{\cdot}0 \text{ per cent}$$

Accordingly, in this particular example, 16 per cent should be added to any estimate of wages cost which is based on ordinary working time.

From the foregoing it will be appreciated that where a night shift or overtime operates, it is important to make suitable allowances in any estimate supplied. The necessity for the percentage balance figure included in the Material and Operation Schedule forms, Figs. 249 and 254, will be apparent, because it is from the knowledge of the percentage which the operator normally makes that the actual time to be taken for any given work can be assessed and used by the costs accountant for evaluating the amount of "cost of living" bonus to be included in the wages figure. Tables XIX, XX, and XXI, and similar tables, covering the full range of rates applicable, will give information which will be very helpful, and all estimators will be well advised to draw up a comprehensive set in order to provide short cuts.

Estimates Involving Reorganization Schemes

Let us now consider the other form of estimating mentioned at the beginning of the chapter. An estimate is required in connection with an extension or a partial reorganization of the factory, or of a particular department, and it has to be submitted to the Board for approval. Much of the preliminary information will require to be furnished by the plant and machinery assistant. Actual quotations for new buildings, equipment, and plant, combined with the experience of the past,

will generally provide the major part of the detailed information required to compile the estimate.

For the sake of clarity, it is recommended that the work should be finally divided into eight distinct sections as follows—

Section 1. Particulars of existing registered plant which is to be displaced.

Section 2. Particulars of existing registered plant which is to be retained but transferred into a new position.

Section 3. Particulars of new machines and equipment to be installed.

Section 4. Particulars of new equipment to be provided, apart from the installation of registered machines.

Section 5. Particulars of unregistered equipment to be displaced.

Section 6. Particulars of unregistered equipment to be re-arranged.

Section 7. Particulars of structural engineering work to be carried out.

Section 8. Particulars of electrical engineering work to be carried out.

Fig. 259 gives an indication of what is required to enable the estimate to be completed. Although only one item is shown here under each section, it will be appreciated that in practice there may be a considerable number of

TABLE XIX

GROSS HOURLY RATE IN SHILLINGS FOR BONUSES OF VARYING PERCENTAGES

Weekly Base Rate (47 Hours)	Percentage Bonus												Weekly Base Rate (47 Hours)
	25	30	35	40	45	50	55	60	70	80	90	100	
10s.	·266	·277	·287	·298	·308	·319	·330	·340	·362	·383	·404	·425	10s.
12s.	·319	·332	·345	·358	·369	·383	·395	·409	·434	·450	·485	·521	12s.
14s.	·372	·387	·402	·417	·431	·447	·461	·476	·506	·529	·566	·596	14s.
16s.	·426	·443	·460	·477	·493	·511	·526	·545	·579	·613	·647	·681	16s.
18s.	·479	·498	·517	·536	·554	·575	·592	·613	·651	·690	·728	·766	18s.
20s.	·532	·553	·574	·596	·616	·638	·660	·681	·724	·766	·808	·849	20s.
22s.	·585	·608	·632	·655	·677	·702	·724	·749	·796	·843	·889	·936	22s.
24s.	·628	·664	·689	·715	·739	·766	·790	·817	·868	·919	·970	1·021	24s.
26s.	·692	·719	·748	·775	·800	·830	·856	·885	·940	·996	1·052	1·106	26s.
28s.	·745	·774	·804	·834	·862	·894	·921	·952	1·013	1·069	1·131	1·191	28s.
30s.	·798	·830	·862	·894	·923	·957	·989	1·021	1·087	1·149	1·211	1·274	30s.
32s.	·851	·885	·919	·953	·985	1·021	1·053	1·089	1·151	1·226	1·293	1·362	32s.
34s.	·905	·940	·977	1·013	1·047	1·085	1·119	1·151	1·230	1·302	1·375	1·447	34s.
36s.	·957	·996	1·034	1·072	1·108	1·149	1·185	1·226	1·302	1·379	1·456	1·532	36s.
38s.	1·011	1·051	1·091	1·122	1·170	1·213	1·252	1·294	1·375	1·456	1·536	1·615	38s.
40s.	1·064	1·106	1·149	1·198	1·231	1·277	1·319	1·312	1·449	1·532	1·615	1·698	40s.
42s.	1·117	1·162	1·206	1·251	1·293	1·340	1·382	1·428	1·519	1·588	1·697	1·787	42s.
44s.	1·170	1·217	1·264	1·310	1·354	1·404	1·448	1·498	1·591	1·685	1·779	1·812	44s.
46s.	1·224	1·273	1·321	1·371	1·416	1·469	1·514	1·566	1·663	1 758	1·856	1·957	46s.
48s.	1·277	1·328	1·378	1·430	1·478	1·532	1·579	1·634	1·736	1·838	1·941	2·042	48s.
50s.	1·330	1·383	1·436	1·486	1·539	1·595	1·649	1·702	1·811	1·915	2·019	2·123	50s.
52s.	1·383	1·438	1·495	1·549	1·601	1·660	1·711	1·770	1·881	1·992	2·104	2·212	52s.
54s.	1·430	1·493	1·551	1·609	1·663	1·724	1·777	1·838	1·953	2·069	2·183	2·292	54s.
56s.	1·489	1·549	1·608	1·668	1·724	1·787	1·842	1·904	2·024	2·118	2·262	2·383	56s.
58s.	1·543	1·604	1·665	1·728	1·785	1·851	1·908	1·984	2·097	2·221	2·345	2·468	58s.
60s.	1·596	1·660	1·724	1·787	1·847	1·915	1·979	2·042	2·173	2·298	2·421	2·547	60s.

TABLE XX

Conversion of Working Times to Piecework Prices (assuming an Average Bonus of 50 per cent is Earned)

Base Rate 47 hr week	6s	8s	10s	12s	14s	16s	20s	34s	35s	36s	37s	38s	40s	42s	44s	46s	48s	50s.
Time Taken	Equivalent Piecework Price in Pence																	
1 min	038	051	064	077	089	102	128	217	224	230	236	243	255	268	281	294	306	319
2	077	102	128	153	179	204	255	434	447	460	472	485	511	536	562	587	613	639
3	115	153	192	230	267	306	383	654	671	689	709	728	766	804	843	881	919	958
4	153	204	255	306	357	408	510	868	894	919	945	970	1 022	1 072	1 124	1 175	1 226	1 277
5	192	255	319	383	447	511	639	1 086	1 118	1 149	1 181	1 213	1 277	1 341	1 405	1 469	1 532	1 597
6	230	306	383	460	534	613	756	1 303	1 342	1 379	1 417	1 456	1 532	1 609	1 685	1 762	1 839	1 916
7	268	357	447	536	635	715	894	1 520	1 565	1 609	1 653	1 698	1 788	1 877	1 926	2 056	2 145	2 235
8	307	409	511	613	715	817	1 021	1 737	1 789	1 838	1 890	1 941	2 043	2 145	2 247	2 350	2 451	2 554
9	345	460	574	690	814	919	1 148	1 954	2 012	2 068	2 126	2 183	2 299	2 443	2 528	2 643	2 758	2 874
10	383	511	638	766	894	1 021	1 276	2 171	2 236	2 298	2 362	2 426	2 554	2 681	2 809	2 937	3 064	3 193
20	766	1 021	1 277	1 532	1 787	2 042	2 552	4 342	4 472	4 596	4 724	4 852	5 108	5 362	5 618	5 874	6 128	6 386
30	1 149	1 532	1 915	2 298	2 671	3 063	3 828	6 543	6 708	6 894	7 086	7 278	7 662	8 043	8 427	8 811	9 192	9 579
40	1 532	2 043	2 554	3 064	3 575	4 084	5 104	8 684	8 944	9 192	9 448	9 704	10 216	10 724	11 236	11 748	12 256	12 772
50	1 916	2 554	3 192	3 831	4 469	5 105	6 388	10 855	11 180	11 490	11 810	12 130	12 770	13 405	14 045	14 685	15 320	15 965
60	2 297	3 064	3 830	4 600	5 342	6 126	7 656	13 026	13 416	13 788	14 172	14 556	15 324	16 086	16 854	17 622	18 386	19 158
5 hrs	11 493	15 321	19 152	22 983	26 811	30 630	38 280	65 13	67 08	68 94	70 86	72 78	76 62	80 43	84 27	88 11	91 93	95 79

TABLE XXI

Conversion of Piecework Prices to Working Times (assuming an Average Bonus of 50 per cent is Earned)

Base Rate 47 hr week	6s		8s		10s		12s		14s		16s		20s		34s		35s		36s		37s		38s		40s		42s		44s		46s		48s		50s	
	Equivalent Working Time																																			
Piecework Price	H	M	H	M	H	M	H	M	H	M	H	M	H	M	H	M	H	M	H	M	H	M	H	M	H	M	H	M	H	M	H	M.	H	M	H	M
s d																																				
1		26 00		19 50		15 75		13 00		11 25		9 75		7 75		4 50		4 50		4 25		4 25		4 00		4 00		3 75		3 50		3 50		3 25		3 25
3	1	18 25		58 75		47 00		39 25		33 50		29 50		23 50		13 75		13 50		13 00		12 75		12 25		11 75		11 25		10 75		10 25		10 00		9 50
6	2	36 75	1	57 50	1	34 00	1	18 25	1	7 25		58 75		47 00		27 75		26 75		26 25		25 50		24 75		23 50		22 50		21 50		20 50		19 75		19 00
9	3	55 00	2	56 25	2	21 00	1	57 50	1	40 75	1	28 25	1	10 50		41 50		40 25		39 25		38 00		37 00		35 25		33 50		32 00		30 75		29 75		28 50
1 0	5	13 25	3	55 00	3	8 00	2	26 75	2	14 25	1	57 50	1	34 00		55 25		53 75		52 25		50 75		49 50		47 00		44 75		42 75		41 00		39 25		37 75
1 3	6	31 75	4	53 75	3	55 00	3	15 75	2	47 75	2	27 00	1	57 50	1	9 00	1	7 25	1	5 25	1	3 50	1	1 75		58 75		56 00		53 50		51 25		49 25		47 20
1 6	7	50 00	5	52 50	4	42 0	3	55 00	3	21 50	2	56 25	2	21 00	1	23 00	1	20 50	1	18 50	1	16 25	1	14 25	1	10 50	1	7 25	1	4 25	1	1 50		59 00		56 75

ESTIMATED COST OF NEW WORKS

Estimate No. *67*

Description of Scheme *Reorganization of Machine Shop* Date *1st March, 1940*

Proposed Work	Purchase of Plant	Work by own Company	Work by Contractors	Total
	£	£	£	£
NEW WORK				
Providing and Fixing—				
Machine No. 48 Radial Drill	225 (3A)	12 (3B)	—	237 (3C)
Gauge Racks		30 (4C)	—	30 (4C)
Electric Points		25 (8A)	—	25 (8A)
Removing and Refixing				
Office Furniture		6 (6A)		6 (6A)
Providing				
Concrete Foundations and Flooring	—	—	95 (7A)	95 (7A)
(*a*) TOTAL	£225	£73	£95	£393
REMOVAL OF EXISTING WORKS				
Machine No 33 Vertical Drilling Machine		4 (1D)		4 (1D)
60 ft of Shafting		6 (5D)		6 (5D)
(*b*) TOTAL		£10		£10
TRANSFERRING EXISTING ASSETS TEMPORARY WORKS AND OTHER PURELY REVENUE CHARGES				
Removing and Refixing				
Machine No 38 Tool Grinder		6 (2D) (2E)	—	6 (2D) (2E)
(*c*) TOTAL		£6		£6
(*d*) GROSS EXPENDITURE	£225	£89	£95	£409
DEDUCTIONS				
Credit for recoverable material—				
Machine No 33 Vertical Drilling Machine	-	—	—	5 (1E)
60 ft of Shafting		—	—	2 (5E)
(*e*) TOTAL DEDUCTIONS	—		—	7
(*f*) NET COST (*d* *e*)	£225	£89	£95	£402
Original cost of works displaced				
Machine No 33 Vertical Drilling Machine	80 (1A)	8 (1B)		88 (1C)
60 ft of Shafting	20 (5A)	10 (5B)		30 (5C)
(*g*) TOTAL COST OF DISPLACED WORKS	£100	£18	—	£118
Estimated cost of replacing at present prices works displaced —				
Machine No. 33 Vertical Drilling Machine	96 (1F)	10 (1G)	-	106 (1H)
60 ft. of Shafting	24 (5F)	12 (5G)		36 (5H)
(*h*) TOTAL PRESENT DAY REPLACEMENT COST	£120	£22	—	£142

(Signed)

WORKS MANAGER.

FIG. 260 NEW WORKS ESTIMATE FORM

items under any or every one of the sections. For our purpose we will assume that the one item quoted represents the total amount involved for the appropriate section.

With the information compiled on Form, by the use of which he is able to prepare a New Works Allocation Form, Fig. 261. The letters included in Figs. 260 and 261 are merely to show the connection between the various sums of money enumerated.

ALLOCATION OF ESTIMATED COST OF NEW WORKS

Estimate No. *67* Date *4th March, 1940*

Description of Scheme *Reorganization of Machine Shop*

			£
Expenditure on new work			(*a*) 393
Less Estimated cost of replacing at present prices the works displaced			(*h*) 142
Addition or Improvement			(*j*) £251

ALLOCATION

CAPITAL ACCOUNT			£
Addition or Improvement			(*j*) 251
REVENUE		£	
Replacement work	(*h*)	142	
Removal of existing works	(*b*)	10	
Transferring existing assets, temporary work, and other purely revenue charges	(c)	6	
		£158	
Less Credit for recoverable material	(*e*)	7	
Total			£151
NET COST			(*f*) £402

(Signed)

WORKS COSTS ACCOUNTANT

FIG. 261 NEW WORKS ALLOCATION FORM

the lines outlined, the next step is to prepare a New Works Estimate Form, the type of form suggested being shown in Fig. 260. It will be seen that provision is made in this form for credits for displaced plant. The work of the estimating office is now completed, and it only remains for the works accountant to do his part. The latter is supplied with a copy of the completed New Works Estimate

Thus it is seen, from the accountant's allocation of the gross expenditure, what is the ultimate effect on the capital of the firm, i.e. the amount by which it is estimated the capital is to be increased or decreased, and on the amount to be taken from revenue. This method of presenting an estimate should not be confused with the preparation of a balance sheet, which provides for the installation of new

CAT. Nos. 5/52701 TO 52730 INCL.

CATALOGUE No	DRG MARK No	ESTIMATE No			CATALOGUE No	DRG MARK No	ESTIMATE No		
5/52701					5/52716				
5/52702	5/10674	2345			7	3/14055	2613		
3					8				
4					9				
5	8/10674	2351			20	13/10795	2614		
6					1	14/10795	2317		
7					2				
8					3	14/12211	2353		

FIG. 262. CARD FOR INDEXING CATALOGUE NUMBERS WITH REFERENCE TO ESTIMATE NUMBERS

DRG. No 12654.

DRG MARK No	ESTIMATE No			DRG MARK No	ESTIMATE No		
1/12654	1960			17/12654			
2/ "	3023			18/ "	3023		
3/ "	3023	3416		19/ "	3022	3415	
4/ "				20/ "	3024		
5/ "				21/ "	3024		
6/ "				22/ "			
7/ "				23/ "	3025		
8/ "				24/ "			

FIG. 263. CARD FOR INDEXING DRAWING NUMBERS WITH REFERENCE TO ESTIMATE NUMBERS

SPANNERS

DESCRIPTION	ESTIMATE No			DESCRIPTION	ESTIMATE No		
SPANNER FOR GLAND NUTS	1806			1" x 1⅛" RING SPANNER	4788		
SPANNER FOR PIPE JOINTS	1807			3/8" WHITWORTH SPANNER	4842		
VARIOUS SPANNERS FOR				SPANNER FOR MECHANICAL			
USE ON BRASS DETAILS.	3260			LUBRICATOR PUMP	4950		
½" CLOSED SPANNER	4950						

FIG. 264. ALPHABETICAL CARD INDEX OF MANUFACTURED ITEMS

plant and displacement of staff, and shows the anticipated savings. (See Chapter VII.) Even in this case, however, it may also be necessary for the balance sheet to be supplemented by estimate and allocation forms, similar to Figs. 260 and 261.

Reference Files

For quick reference an estimate number should be allocated to each completed estimate and, in addition to a book register of all such estimates entered in numerical order, three card records should be maintained. These latter are all necessary, as different departments may quote different references when seeking information.

The arrangement of the card records recommended is illustrated and may be briefly explained as follows –

No. 1. *Card indexing catalogue numbers and giving reference to estimate numbers.* (Fig. 262.) It will be noted that provision is made for more than one estimate number in this record, in order that the estimate number applicable to an assembled article may be shown in addition to the estimate number for the individual units.

No. 2. *Card indexing drawing numbers and giving reference to estimate numbers.* (Fig. 263.) The digits indicate the reference to the details on the drawing. Where no entry has been made at the side of the digit it indicates that no estimate has been provided. In this instance also it will be noted that provision is made for more than one estimate per mark number. In the case of an estimate for an assembled article which consists of a number of details, the estimate number of the assembled article should be entered on this record for reference, even though the original estimate number for each of the separate details will be used for ordering purposes.

No. 3. *Card indexing alphabetically all manufactured items.* (Fig. 264.) All these records should be entered together and should prove a ready means of tracing any estimate. A convenient size for each of the cards is 5 in. × 8 in. The estimates themselves should be arranged in strict numerical order in cabinets. It is strongly recommended that all calculations which require to be made should be kept with the completed estimate.

CHAPTER XXII

PRODUCTION PLANNING

Functions of Production Planning Department

The satisfactory and economic control of the manufacture and assembly of any equipment demands careful supervision and attention to detail. For this purpose the adoption of a central production planning system has everything to commend it. Its importance as an integral part of the works organization can scarcely be overestimated, and if well organized its advantages are indeed very real. The functions of this key department should be briefly as follows—

(1) To concentrate the authority for, and to initiate, actual manufacture.

(2) To prepare manufacturing specifications.

(3) To issue all material requisitions.

(4) To plan the individual operations to be performed, to issue the wages documents incident thereto, and, if the planning is complete, to define the actual machines and other equipment to be used, taking into account the speeds, feeds, and tool set-ups.

Advantages of Central Planning

A central production planning system will prove its efficiency and practical utility in all departments. Its advantages may be summarized as follows—

(1) It is the surest way to obtain manufacturing efficiency.

(2) It centralizes the clerical work which must otherwise be carried out by the foremen, chargemen and shop clerical staff, most of whom would have varying ideas as to how it should be done and would act accordingly. Such centralization minimizes the amount of clerical work in the aggregate.

(3) It ensures that the materials and wages systems of the works are conducted on uniform lines.

(4) It ensures that all material received from outside firms is debited to the appropriate order, and concentrates the responsibility for the correct ordering of all material required for that order, viz. material manufactured in the works as well as that obtained from outside manufacturers.

(5) It enables the works costs accountant to arrive at an accurate cost for any equipment completed, as wages and material cannot be charged to an order other than that quoted on the requisitions and wages tickets supplied by the production planning office.

(6) Any material which has been scrapped can be credited to the individual works order and new requisitions made out for replacement purposes. This practice obviates the necessity for inquiries in the shops concerning surplus charges.

(7) It enables a record to be kept of

the whole of the material used in the manufacture of all classes of work. These records may be filed for easy reference.

(8) A system of scheduling completed work is made possible, enabling the progress of an order to be seen at any time, and also revealing any delay which may be occurring.

WORKS ORDER NO. *2856* DATE *25th July, 1940*

CORRESPONDENCE REFERENCE *EJL 570*

DESCRIPTION *Ten Heavy Oil Engines*

INSTRUCTIONS. The drawings supplied by the Contractor must be closely followed in every detail. Each Engine is to have a plate affixed giving a distinctive number, i.e. E 1—E 10

DRAWINGS. General Arrangement Drawing No G 532 includes a list of the detailed drawings involved.

WORK TO BE CARRIED OUT Complete manufacture of ten units, including certain attachments.

AUTHORITY. Directors' Committee Minute No 1989 dated 24th July, 1940

REPORT. The work must be regarded as urgent, and as soon as each unit is completed an advice is to be sent to the Progress Office.

FIG 265. WORKS ORDER

Standard Documents

Before going more fully into the operation of this system, in which a number of standard forms and documents are recommended, it is necessary to give a brief description of them and their uses. They cover a variety of purposes as follows –

1. *The Works Order.* The works order, Fig. 265, is a circular to be sent to all assistants, offices and shops concerned as soon as an order for any new work has been authorized, giving a brief description of the work and the order number to which the work is to be charged. The words in capital letters constitute the printed portions of the form.

2. *Material Lists.* Material lists should be supplied by the drawing office to the production planning office, when the works order (Form No. 1) authorizing the work has been received. These lists should show the bulk quantity of material and any special fittings required. Two copies should be passed forward to the storekeeper, enabling him to place orders with contractors for such items as steel plates when of special sizes, or to supplement his stock of raw materials when the articles in question can be made from standard stocked sizes of material. In due course, the storekeeper should return one of the lists showing the source of supply.

3. *Delivery Lists.* Delivery lists, Fig. 266, should be prepared, and actual deliveries recorded as advices are received from the storekeeper. This information should be passed to the shops concerned, to keep them advised of the availability of the material.

4. *Material Ordering Specification of Details.* The "material ordering specification," Fig. 267, should comprise a

MATERIAL ORDERED FOR ORDER *2856 = 10 Engines.* *2857 = 10 Engines.* *2858 = 15 Engines.*

Quantity per Unit	Description	Dimensions	Weight per Unit c	q	lb	Pattern No.	Reqn No	Date	Identification No	Date Pattern sent	Where Ordered	Delivery
2	*Steel Stiffening Plate*	*2 ft 6 in × 1 ft 6 in × ½ in*		*2*	*20*		*D. 699*	*1 9 39*	*6,72*		*Fern & Co*	*⅓rd 12/11/39* *⅔rds 31/12/39*

1	2	3	4	5	6	7	8	9	10	TOTAL	REJECTED MATERIAL Reqn No	Date	Quantity	REPLACEMENTS	REMARKS
2	*2*	*2*	*2*	*1 13/10/3 1*	*2*	*2*	*2*	*2*	*2*	*70*					
2 *2*	*2* *2*	*2* *2*	*2* *2*	*2* *2*	*2* *2*	*2* *2*	*2* *2*	*2* *2*	*2* *2*						
2	*2*	*2 21/10/38*	*2*	*2 31/12/38*											

FIG 266 MATERIAL DELIVERY LIST

MATERIAL ORDERING SPECIFICATION

Works Order No. *2856*

Shops	Cat No.	Qty. per Set	Description of Article	Dig No	Manu-facturing Ident No	Material: 1st Five	2nd Five		(G)		
(A)	(B)	(C)	(D)	(E)	(F)						
12 & 6		2	Steel connecting Link Spec'n 25. O.H. Acid 32/38 tons tensile	1/2684	3/310	68	752				
6			Steel pin for connecting link Spec'n 37	2/2684	3/311	68	753				
6		4	Steel collar for connecting link Spec'n 37	3/2684	3/312	68	754				
6	14/5286	4	$\frac{3}{16}$ in. Split Cotter for connecting link pin	2684	3/314	68	755				

FIG. 267. MATERIAL ORDERING SPECIFICATION OF DETAILS

SPECIFICATION AND LIST OF MATERIAL REQUIRED

Works Order No. *2856*

No. per Set	ARTICLE	Ident. No.	Drawing No	Cat. No. or Manufacturing Shop	REMARKS
2	*Steel connecting link*	*3/310*	*1/2684*	*12 & 6 Shop*	
4	*Steel pin for connecting link*	*3/311*	*2/2684*	*6 Shop*	
4	*Steel collar for connecting link*	*3/312*	*3/2684*	*6 Shop*	
4	$\frac{3}{16}$ *in. Split cotter for connecting link pin*	*3/314*	*2684*	*14/5286*	*Normal stock*

FIG. 268. MANUFACTURING SPECIFICATION LISTS

form to be used solely by the production planning office, on which a "specification" of the various details should be recorded from the drawings, giving the quantity required per unit, the description of the article, its drawing number, the shops concerned in its manufacture, the manufacturing identification number of the detail, and the number of units for which material has been ordered.

5. *Stock Lists.* These should be prepared from the information included on the "specification of details" forms, and should contain the bulk quantity of manufactured stock details which will be required for the order under construction. They should be submitted to the storekeeper as early as possible in order that he may make provision for stock items which he will be called upon to supply at a later date of which he will be advised.

6. *Manufacturing Specification Lists.* These should show what number of each article is required per unit, the description of the article, and its manufacturing identification number, drawing number, catalogue number or manufacturing shop number. These lists, Fig. 268, should be issued to all shops and should form a complete description of every detail required for an individual order.

7. *Requisitions.* Requisitions, Figs. 269 and 270, should be issued to the shops for every detail and should constitute the authority for obtaining the rough material, or a finished article from the stores.

8. *Conveyance Notes.* Conveyance notes, Fig. 271, should be issued with the requisitions for work handled by more than one shop or section, giving the description of the article, its identification number, order number, and the shops concerned in its manufacture. The conveyance notes should accompany the articles to be produced until ready for assembly, and when the articles have been handed over to the assembly shop, the conveyance notes should be returned to the production planning office.

9. *Operation Sheets.* On the "operation sheets," Fig. 273, should be recorded the individual operations for each manufactured detail (see Fig. 272), the number required per unit, the identification numbers, drawing number, and the wages tickets as they are issued.

10. *Wages or Job Tickets.* Wages tickets, Figs. 274, 275 and 276, should be supplied to the shops for every operation. No work should be carried out except that which is authorized in this way.

11. *Scrap Material Orders.* These forms, Fig. 277, should be signed by the foreman in whose shop the article is scrapped, giving full particulars of the detail, and should be a notification that new material is to be ordered to replace scrap, and new wages tickets are to be issued to cover the various operations which occurred before scrapping. To avoid a double charge the shop responsible for the defects should be debited, the appropriate factory order being stated on the wages tickets issued.

12. *Credit Notes.* "Credit notes," Fig. 278, should be issued for the crediting of material as scrap in the case of scrapped articles, or into stock

STORES REQUISITION

No $\frac{P}{O}$ 65752

Material as under to be delivered at Shop No *12*

Charge to *0 2856* *3 310* *(10 Sets)*

Quantity Required	Description and Drawing Number
20	*Steel connecting link Drg 1 2681*

Signature Date

Date supplied	Grade of Material		Weight (A) Cwt Qr Lb	Cost (B) Rate Amount
	Specification 25 O H Acid 32 38	Rough		
	Catalogue No	Weight used		
	30 28	To Scrap		

FIG 269 MATERIAL REQUISITION

(Column (*A*) will be completed by the Shop and Column (*B*) by the Accountant)

CASTINGS ISSUE NOTE

No *1009*

Shop *4* Date *2nd August 1940* Charge *0 2856*

Material to be delivered to *6 Shop* Signature

Mixture No *B 2*

Catalogue No	DESCRIPTION	Quantity	Charge on Account Tons	C	Q	lb	Rate	£	s	d
19/275	*Brass oiling ring 2¾ in outside diameter*	*20*								
		Gross Weight								
		Scrap Standard Weight								
		Net Weight								

Quantity outstanding to complete order

Date received in store

Received by

FIG 270 CASTINGS ISSUE NOTE

MATERIAL CONVEYANCE NOTE		Date	2nd August, 1940	
Order No.	**Quantity**	**Description and Drawing Number**	**From Shops**	**Completed**
2856	*20* = *10 Sets*	*Steel connecting link* *Drg. 1/2684*	*12*	
Ident. No.			*6*	
3/310				
Req'n. No.				
68752				

When completed deliver to *10* Shop. Date received

On completion of order, this form to be returned to *Central Planning Office.*

FIG. 271. CONVEYANCE NOTE

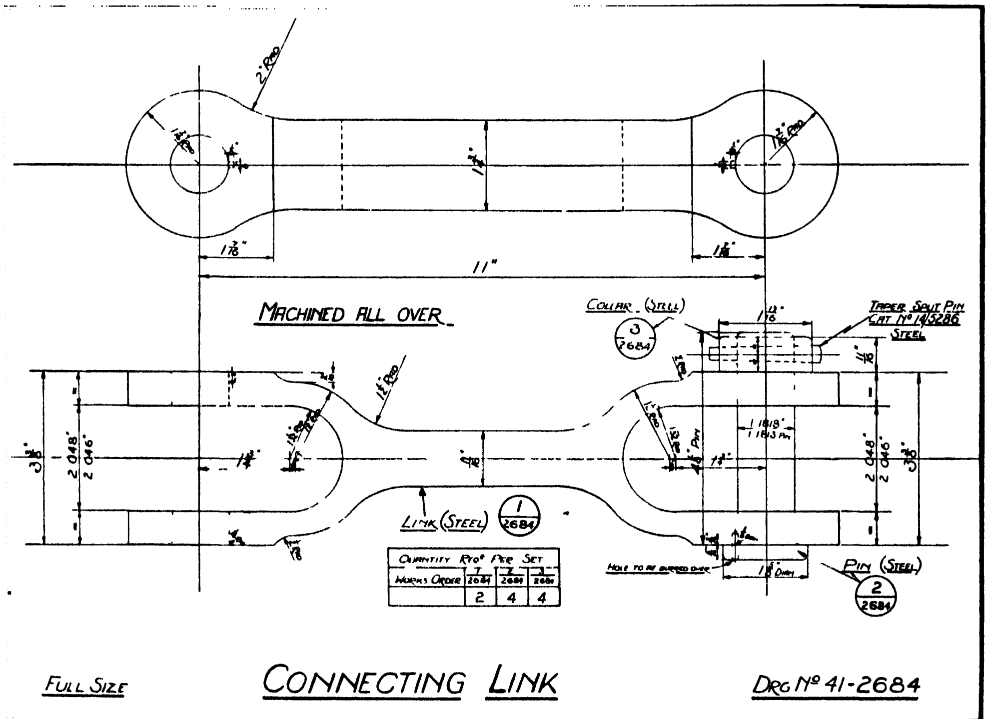


FIG. 272. CONNECTING LINK

OPERATION SCHEDULE

Works Order No

Qty per Set	Description of Article and Drawing No	Manufacturing Ident No	Operation No	Description of Operation	Shop and Group Nos	Basis Time Ident No	Basis Time		WAGES TICKETS 1st Set	2nd Set	3rd Set	4th Set	5th Set	6th Set	7th Set	8th Set	9th Set
(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H) h m							(I)			
2	Steel Connecting Link 1/2684	3/310	1	Oxy acetylene cutting	12 2	256	5 0	20					9985				
			2	Smithing	12 1	372	10 0	20					9986				
			3	Planing flats	6/13	112	15 0	20					9987				
			4	Drilling and reamering pinholes from jig	6 11	214	16 0	20					9988				
			5	M O for milling edges	6/21	91	3 20	10			8349			On	in two	only	M O
			6	Milling edges and circling	6/20	112	35 0	10			9989					9990	
			7	M O for slotting jaw and milling flats	6 22	92	2 30	10			8350					8351	
			8	Drilling for slotting jaws	6 11	21	7 30	10			9991					9992	
			9	Slotting jaws both ends	6/18	714	18 0	10			9993					9994	
			10	Milling flats	6 13	113	22 4	10			9995					9996	
			11	M O for feather hole	6/21	93	1 30	20					8352				
			12	Drilling for feather	6/11	216	1 0	20			8353					8354	
			13	Grinding radius on edges	6 12	493	6 30	10			9997					9998	
			14	Buff glazing	6/12	494	1 15	10			8355					8356	
			15	Surface grinding to gauge	6/12	155	4 0	10			8357					8358	
			16	Grinding jaws	6 5	10	12 45	10			9999					0001	
			17	Lapping for pins and radiusing	6/5	142	14 0	10			0002					0003	
4	Steel pins for connecting link 2/2684		18	Fitting details	6/4	172	20 30	4	0004		0005		0006		0007		0008
		3/311	1	Turning and P O	6 17	592	32 0	40					0009				
			2	M O feather holes	6 21	94	5 30	40					0010				
			3	Drilling and reamering for taper pin and drilling for feather	6/11	777 778	12 0	40					0011				
			4	Centring for grinding	6/16	162	1 45	40					8359				
			5	Hardening	6/24	682	4 0	40					8360				
4	Steel collar for do 3/2684		6	Grinding after hardening	6/8	323	4 10	40					8361				
		3/312	1	Turning boring and parting off	6/16	365	18 15	40					0012				

FIG 273 OPERATION SHEET

0 2 4 6 8 Clock No. Name WE Job No. 8349

Year 1 3 5 7 9 Workshop Expe. Rate 1 Operation X 2 Machine No X 3 X Wages £ s d X X 4 Division of Sub Section 7 Sec 8 S Sec. X Clock No Group

Week Shop 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0

(3000) TOTAL TIME TAKEN	Reference	Temporary Slip No	Qty	Article		Operation	Basis Time H	M
HOURS					1			
					2			
	91	-	10	Steel connecting	3	Marking out for		
£ s d				link, 1/2684.	4	milling edges.		
					5			
3 WAGES					6			
						Total	3	20

Time taken Current Week						
Sun	Mon	Tues	Wed	Thurs	Fri	Sat
1	2	4	5	6	7	8

Charge 0/2856 3/310

7 Group Stamp 8 Shop 6. 9 Group 21.

The British Tabulating Machine Co Ltd London W C

FIG 274 PREMIUM WAGES TICKET

(For use when basis time is below say 5 hrs)

0 2 4 6 8 Clock No Name WE Job No 09996

Year 1 3 5 7 9 Workshop Expe. Rate 1 Operation X 2 Machine No X 3 X Wages £ s d X 4 Division of Sub Section X 5 X 6 7 Sec 8 S Sec X Clock No Group

Week Shop 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0

(3000) (A) BASIS TIME		Temporary Slip No.	Qty	Article		Operation
Reference No	HOURS	-			1	
113	22¾	(B) Total Time taken			2	
TIME TAKEN PREVIOUS WEEKS		Hrs.	10	Steel connecting	3	Milling flats.
TIME TAKEN CURRENT WEEK		(C) Time Saved		link, 1/2684.	4	
EXTRA FOR OVERTIME		Hrs	-		5	
1 × C / A PREMIUM		3 Wages for Current Week £ s d			6	Machine No
TOTAL FOR CURRENT WEEK						

1	2	4	5	6	7	8

Charge 0/2856 3/310

7 Chargeman Shop 6. 8 Group 19. 9

The British Tabulating Machine Co Ltd

(front)

DAY	Sun AM	Sun PM	M AM	M PM	Tu AM	Tu PM	W AM	W PM	Th AM	Th PM	F AM	F PM	S AM	S PM				REMARKS
ON																		
OFF																		
ON																		
OFF																		
TOTAL																		

(back)

FIG 275 PREMIUM WAGES TICKET

(For use when basis time justifies clocking on and off)

0 2 4 6 8 Clock No Name W E Job No **05001**
Year
1 3 5 7 9 Workshop

Week	Shop	£ s d	£ s d	£ s d	Engine No	Sec	Sub Sec	Group	Clock No	
0 0	0 0	0 0 0 0 0 0 0 0	0 0 0 0 0 0	0 0 0 0 0 0	0 0 0 0 0 0	0 0 0	0 0	0 0 0	0 0 0 0	0 0

Ident No	Temporary Slip No	(269) Article		Operation	Qty	P W P	Amount £	s	d
			1						
			2						
			3						
			4						
			5						
			6						

Charge | Foreman | Group Stamp | 7 | On A/c No W E | No W E
8 | Total Current Week
Extra for Overtime
9 | Total

HOLLERITH 2829 The British Tabulating Machine Co Ltd Victoria House Vernon Place W C 1 Printed at Letchworth Herts

Fig 276 Piecework Wages Ticket

ARTICLES SCRAPPED IN THE COURSE OF MANUFACTURE

Date No

Shop | Cat No or Ident No | Order No or Stock Order No

Description | Credit to

Charge to

Particulars of Operations involved	Qty	Weight T	c	q	lb	For Accountant's Use — Expenditure incurred on Scrapped Part: Wages	Materials	Workshop Expenses	Total Cost

Cause of Rejection

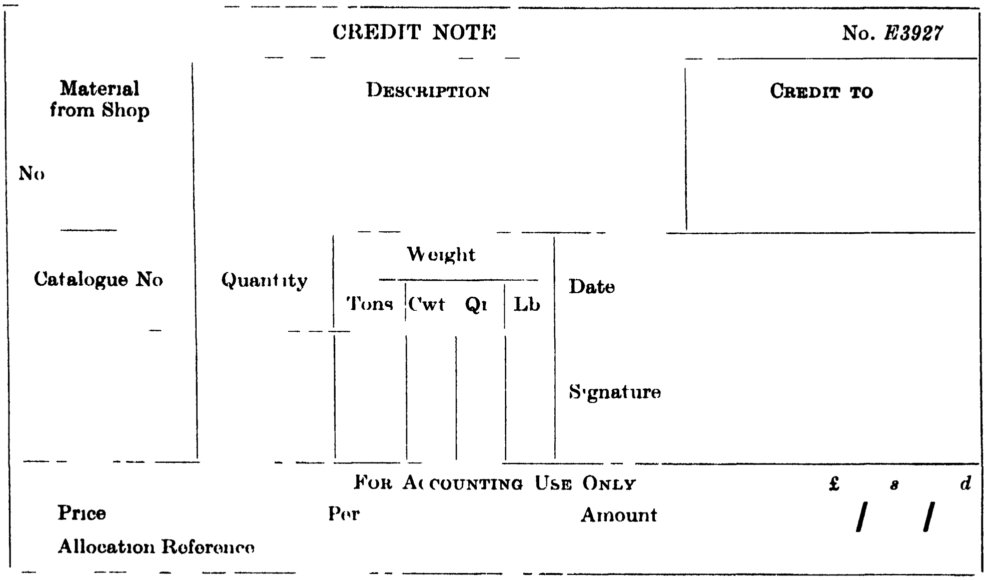
Foreman Rejecting

Fig 277 Scrap Material Order

should the detail not be required for the order for which it was originally ordered.

Operation of Production Planning System

On authority being obtained for the manufacture of new work, everyone


CREDIT NOTE No. *E3927*

Material from Shop

No

Catalogue No

DESCRIPTION

Quantity

Weight

Tons Cwt Qr Lb

CREDIT TO

Date

Signature

FOR ACCOUNTING USE ONLY £ s d

Price Per Amount / /

Allocation Reference

FIG 278 CREDIT NOTE

concerned should be advised to that effect, by means of the works order circular (Form No. 1). As soon as the chief draughtsman receives his copy of the works order he should arrange: (1) For the material lists (Form No. 2) to be supplied to the works showing all special material, viz. plates, steel castings, special fittings, copper and steel pipes, required to the order number. These lists giving quantity, description, dimensions and specification number, should be forwarded to the production planning office, two of them passed on to the storekeeper, one to be retained by him and the other marked "ordered outside" or "stock" and returned to the planning office, who should keep a check on receipts from outside firms and advise the shops concerned of material coming in after having been certified by the materials inspection department.

(2) For the drawings to be marked with the order number in the case of work of a new design or to be remarked with the order number for work where drawings already exist. As the drawings are completed or remarked they should be sent to the works manager's office for signature, formal acknowledgment of receipt being given (see Chapter XX, Fig. 244). Copies of the drawing advice slip should then be issued by the production planning office, one for each shop concerned.

Whether it be, for example, a

machine tool, an internal combustion engine, an aeroplane, a locomotive, or a road motor vehicle which is being manufactured, it is convenient for the purposes of production planning to divide it into classified sections in order to facilitate reference to manufacture, e.g. a motor vehicle might be divided into the following sections—

Section 1. Frame and Fittings, including Front Axle.
Section 2. Engine.
Section 3. Gearbox.
Section 4. Rear Axle.
Section 5. Steering.
Section 6. Wiring.

Every detail should fall within one of these sections and should be given a manufacturing identification number, which is composed of a number representing one of the section numbers of which the article is a part, and a distinctive number which represents that particular part. Thus the cylinder head of a car might be given the identification number 2/8, indicating that it is Item 8 in Section 2, and a cylinder head gasket given the number 2/9 to indicate that it is also in Section 2 and is Item 9. If desired, a letter may be used as the prefix instead of a number, e.g. E/8 and E/9 instead of 2/8 and 2/9 as above.

A technician in the planning office should next prepare, by reference to the drawings, the specification of details (Form No. 4) and should enter the number of each article required per unit, the description of the article and the drawing number, and a non-technical member of the staff should allocate an identification number to each detail, as previously described.

Liaison with Storekeeper

From the "specification of details" sheets, the stock lists (Form No. 5) should be prepared and submitted to the storekeeper, these containing the quantity of each stock item which will be required for the order. By this means he will be able to supplement his stocks to meet the order requirements and not interfere with his normal quantities. He should also be supplied with a programme of work showing the dates on which the erection of the units is to be commenced and completed, in order that his stock details and material from outside firms may be ready when required. From the "specification of details" slip (Form No. 4) the "operation sheets" (Form No. 9) should be made out as follows: Each item, other than stock items, should have its description, identification number, drawing number, and a complete detailed list of operations to be performed upon it, recorded on these sheets, with ample space left on the right-hand side for the insertion of wages ticket numbers to be issued later on.

The "specification lists" (Form No. 6) should next be prepared from the "specification of details" sheets. These lists should give a complete description of all details required for the order, including the number of each article required per unit, the description of each article, its manufacturing identification number, and drawing number. These "specification lists" should be

bound together in book form and constitute a complete specification for the equipment under construction. The whole of the foregoing constitutes preliminary work between the drawing office, planning office, and the stores department, and it remains for the requisitions and wages tickets to be issued for work to commence in the shops.

From the "specification of details" slip (Form No. 4) requisitions and conveyance notes (Forms Nos. 7 and 8 respectively) should be compiled. The requisitions should be completed in triplicate, the original and two counterfoils being sent to the shop concerned for the purpose of obtaining the material from stock. The original copies should be sent to the stores and then forwarded to the accountant for debiting to the appropriate works order numbers. One counterfoil of each requisition should be retained by the shop obtaining the material and these should be filed away in works order and identification number order for reference purposes, and the other counterfoils, after having been signed by the foreman or his representative in the shop as a guarantee of the requisition having been received, should be returned to the production planning office, where they should be filed away in a similar manner to those filed in the shop. The serial number of all requisitions issued should be recorded by the planning office in the space provided on the right-hand side of the "specification of details" slips (Form No. 4).

The conveyance note (Form No. 8) should be made out with one counterfoil, and should state the order number and identification number, quantity ordered on the requisition, description of article, shops concerned, where the article is to be delivered when completed, and there should be columns opposite each shop for the date when the article is completed so far as that shop is concerned. The latter information should be filled in as the article leaves the shops. This form and counterfoil should be sent with the requisition to the shop ordering the material. The counterfoil should be signed as a guarantee of the requisition having been issued, and then returned to the planning office, where it should be filed away. The conveyance note should accompany the article in all operations through the various shops, and on completion of the article should be returned to the planning office, where it should be filed away with the counterfoil of the requisition for that article.

Wages Tickets

Immediately following the issue of requisitions to the shops for obtaining material, the premium or piecework wages tickets (Form No. 10) together with counterfoils should be typed out from the "operation sheets" (Form No. 9) for every operation on each detail. A counterfoil of each wages ticket should be retained in the planning office for checking the charge when the work is completed, and the wages ticket should be sent to the shops concerned in readiness for the work being put in hand. When these wages tickets are sent to the shops a horizontal line should be drawn

through the issues column on the operation sheets by the production planning office staff, showing the number of units for which the articles on the wages tickets are required. On the counterfoil of the wages ticket should be stamped the date of issue, so that if the ticket should get mislaid in the shops it is easy to see, by referring to the sheets, whether the tickets have actually been issued, and, by reference to the counterfoil, to ascertain the actual date issued, thus preventing over-charging to the order.

As the work is completed, the wages tickets should be returned through the planning office, where they should be inspected and marked off on the operation sheets, showing that the particular operation for the article has been carried out, the counterfoil for the wages ticket being endorsed with the date charged, and the wages tickets being forwarded to the wages office for payment. It will thus be seen that by reference to the operation sheets the progress of the work can be ascertained at any time. For a more detailed explanation reference should be made to Chapter XXIII.

Scrap Material

In all cases where material for an order is scrapped, due either to defective material or machining errors, the chargeman on whose section the article is scrapped should send a "scrap material order" (Form No. 11) signed by his shop foreman, to the production planning office. This slip should give the order number, identification number, and description of the article, the operation during which it was scrapped, and the cause. On the back of the form should be recorded the operations affected, for which duplicate wages tickets will have to be provided. Furthermore, an additional requisition for new material will be required.

A copy of the scrap material order should be prepared by the planning office and sent to the accountant for allocation. As the value of the scrap material will require to be credited to the order, a credit note (Form No. 12) covering it should be made out, with two counterfoils, in the planning office and the original sent to the costs accountant to enable him to credit the order number with the value of the material. One counterfoil should be filed in the planning office and the other retained by the shop concerned, or by the stores department in all cases of stock items.

Faulty Workmanship or Rectification of Faulty Material

It should be specially noted that where an item is in progress of manufacture and at a certain operation it is found to be defective, none of the wages charges up to the time of the defect being found should be charged to the particular order, but a proper allocation of the amount involved should be made. It is not easy to lay down a hard and fast rule as to whether the contractor supplying the material should be held responsible for the expenditure incurred, which will depend on the terms of the contract. If the article is not a scrap, as for instance a steel casting which requires rectification by welding due to

porosity, or by straightening due to distortion, and this work cannot be charged to an outside source because the article has been manufactured in the works, then generally the amount incurred should be debited to the appropriate factory order and to the shop at fault.

Where charges have already passed through, the new wages tickets which are issued to cover the same operations on the replace article should be charged specially, in order that the charges may be segregated. The original wages tickets which have not been used in the first case will be available for the replace article. In no circumstances should a double charge for any material or operation be permitted.

Stores Demand and Recovery Note

It is appropriate to consider here that in some circumstances Hollerith cards may be preferred instead of forms for requisitions. Fig. 279 shows a combined stores demand and recovery note. In the particular case shown the document has been written out in the shops, and is a request for four new covers from stores and the return of four scrap covers to stores. The money values have been inserted by the accountant. Fig. 280 shows the same document after passing through the accountant's punching machine, and Fig. 281 shows a "master" card with holes correspondingly punched.

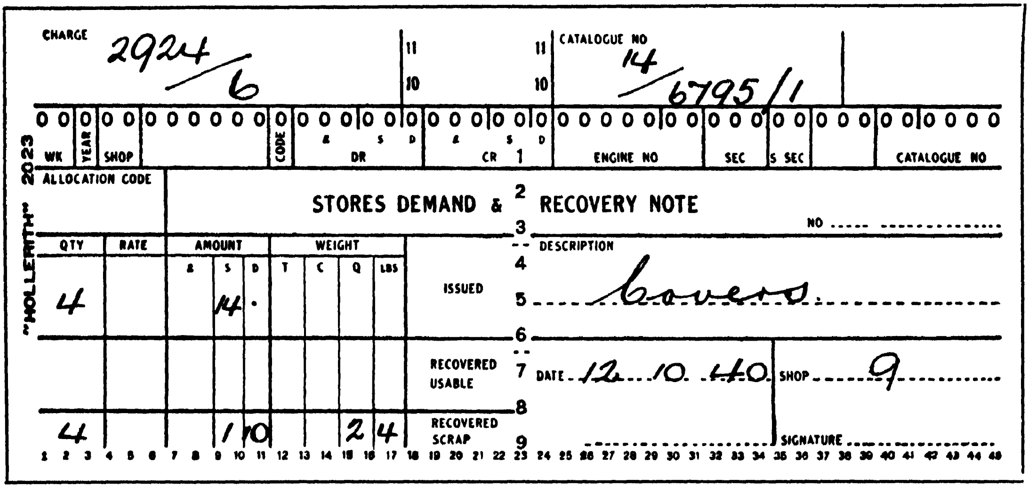

CHARGE 2924/6
CATALOGUE NO 14/6795/1
WK YEAR SHOP CODE £ s D DR £ s D CR ENGINE NO SEC S SEC CATALOGUE NO
"HOLLERITH" 2023
ALLOCATION CODE
STORES DEMAND & RECOVERY NOTE
NO
QTY RATE AMOUNT £ s D WEIGHT T C Q LBS DESCRIPTION
ISSUED 4 14 · Covers
RECOVERED USABLE DATE 12. 10. 40. SHOP 9
RECOVERED SCRAP 4 1 10 2 4 SIGNATURE

FIG. 279. COMBINED STORES DEMAND AND RECOVERY NOTE

Repetition Work

Whenever repetition work is involved, as for instance stock order work, it is strongly recommended that for each item a standard planning card be prepared giving particulars of the material required, classes of machines to be used, operations and grades of operator required. In this connection information of the type given in Tables XXII, XXIII, and XXIV will

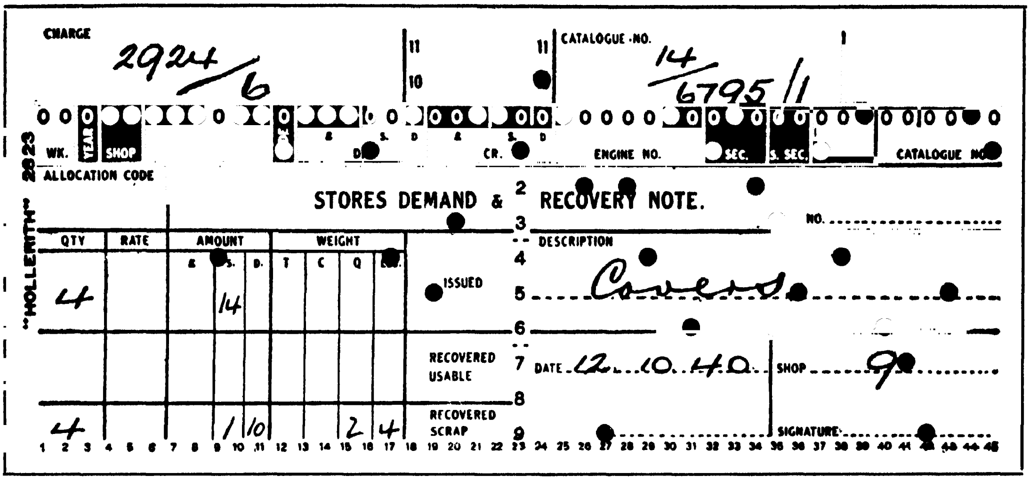


FIG. 280. CARD SHOWN IN FIG. 279 AFTER PASSING THROUGH PUNCHING MACHINE

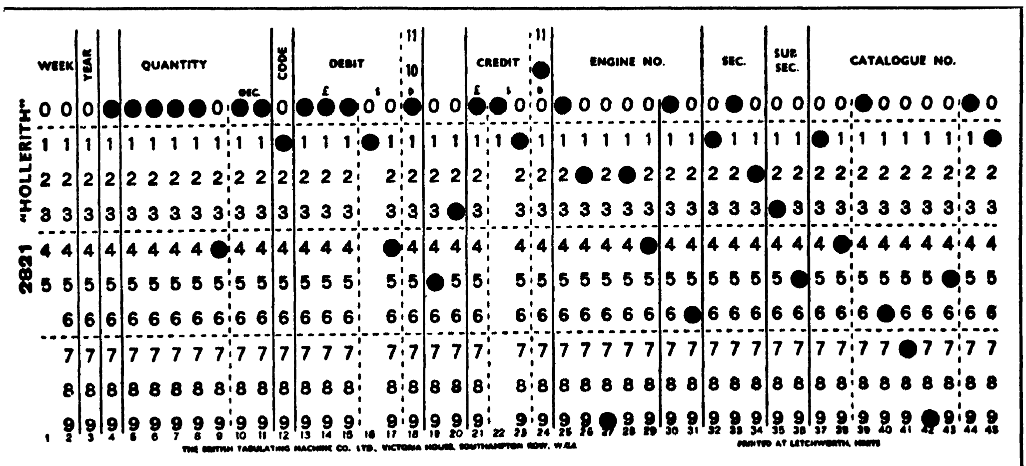


FIG. 281. "MASTER" CARD TO ILLUSTRATE PUNCHING OF HOLES ACCORDING TO INFORMATION ON CARD SHOWN IN FIG. 279

be invaluable in the planning office. For convenience, explanatory notes are given at the foot of each of these if it is drawn up as shown in Fig. 282, the issues columns being used for the insertion of wages ticket and requi-

PLANNING AND PROGRESS CARD.

ARTICLE Pin for Brake. Shaft. CAT No 40/66

DRG No 1409 MIN ORD G Q'TY 20 SHOPS No 12 ESTIMATE No L.2396

STOCK ORDER No	S 12								
QUANTITY	40								
DATE ISSUED	11/2/40								
DATE COMPLETED	1/3/40								

MATERIAL	CAT No	ISSUES							
Specn:- Grade 2 Reeles Acid Steel Bar. 2¼" dia	11/25	365							

OPERATIONS	SHOP	REF	RATE H	RATE M	RATE Q'ty	ISSUES								
Setting up. for turning and parting off Machinist @40/-	12 Semi Auto Group	103	1	40	Per Batch	194								
Turning and parting off Machinist @40/-	12 Semi Auto Group	104	-	20	1	195								
Wabbling cotter hole. Machinist @37/-	12 Small Milling Group	105	-	15	1	196								

FIG 282 COMBINED PLANNING AND PROGRESS CARD

tables. Such tables will also be of great assistance in the estimating and rate-fixing departments. The planning card will also serve as a progress card sition numbers, and the work marked off as the operations are completed. This latter is best done by placing a small red mark, thus √, over the number.

TABLE XXII

Cutting Speeds—Turning

Feet per Minute	460	470	480	490	500	510	520	530	540	550
Diam. in Inches	Revolutions per Minute									
$\frac{1}{4}$	7028	7180	7332	7486	7640	7792	7944	8097	8250	8403
$\frac{5}{16}$	5624	5746	5868	5989	6110	6233	6356	6478	6600	6722
$\frac{3}{8}$	4684	4786	4888	4989	5090	5193	5296	5399	5502	5603
$\frac{7}{16}$	4016	4104	4192	4281	4370	4455	4540	4628	4716	4802
$\frac{1}{2}$	3514	3591	3668	3744	3820	3896	3972	4050	4128	4204
$\frac{5}{8}$	2810	2871	2932	2996	3060	3120	3180	3240	3300	3362
$\frac{3}{4}$	2342	2393	2444	2497	2550	2599	2648	2698	2748	2800
$\frac{7}{8}$	2008	2052	2196	2138	2180	2226	2272	2315	2358	2401
1	1756	1794	1832	1871	1910	1949	1988	2026	2064	2102
$1\frac{1}{8}$	1560	1594	1628	1664	1700	1732	1764	1800	1836	1868
$1\frac{1}{4}$	1406	1437	1468	1499	1530	1559	1588	1619	1650	1681
$1\frac{3}{8}$	1278	1305	1332	1361	1390	1417	1444	1472	1500	1528
$1\frac{1}{2}$	1172	1198	1224	1247	1270	1297	1324	1349	1374	1401
$1\frac{5}{8}$	1082	1105	1128	1154	1180	1202	1224	1248	1272	1294
$1\frac{3}{4}$	1004	1026	1048	1069	1090	1113	1136	1156	1176	1200
$1\frac{7}{8}$	936	956	976	998	1020	1040	1060	1079	1098	1119
2	878	897	916	935	954	973	992	1012	1032	1050
$2\frac{1}{4}$	782	799	816	832	848	866	884	901	918	935
$2\frac{1}{2}$	702	717	732	738	744	770	796	812	828	842
$2\frac{3}{4}$	640	654	668	681	694	709	724	737	750	763
3	586	599	612	624	636	650	664	677	690	701
$3\frac{1}{2}$	502	513	524	535	546	557	568	579	590	601
4	440	450	460	468	476	486	496	506	516	526
$4\frac{1}{2}$	390	399	408	416	424	432	440	449	458	467
5	352	359	366	374	382	390	398	405	412	420
$5\frac{1}{2}$	320	327	334	340	346	354	362	368	374	381
6	292	299	306	312	318	324	330	337	344	350
7	250	256	262	267	272	277	282	288	294	300
8	220	225	230	234	238	243	248	253	258	262
9	194	198	202	207	212	216	220	225	230	234
10	176	179	182	186	190	194	198	202	206	210
11	160	163	166	170	174	177	180	184	188	191
12	146	149	152	155	158	162	166	168	170	174
13	136	139	142	144	146	149	152	155	158	161
14	126	128	130	133	136	139	142	144	146	149
15	118	120	122	124	126	129	132	134	136	139
16	110	112	114	116	118	121	124	126	128	131
18	98	100	102	104	106	108	110	112	114	116
20	88	89	90	92	94	96	98	101	104	105
25	70	72	74	75	76	77	78	79	80	83
30	58	60	62	63	64	65	66	67	68	69

Explanatory Notes to Table XXII

Suppose an item is to be turned on a face of 14 in. dia. for a distance of 6 in., one cutting only being required and the cutting speed per minute and number of feeds per inch being respectively 510 ft. and 50. Then from the table it will be seen that, to give the required cutting speed, the work must be revolved at a speed of 139 r.p.m.

The total number of revolutions of the work required to complete the cutting operation is given by—

$$\text{No. of feeds per inch} \times \text{length of traverse} = 50 \times 6 = 300.$$

Therefore the time required for the actual cutting operation will be—

$$\frac{\text{Total no. of revolutions required}}{\text{Speed of work in r.p.m.}} = \frac{300}{139} = 2{\cdot}16 \text{ min.}$$

TABLE XXIII

Cutting Speeds—Slotting and Shaping

Ratio—Cutting to Return 2 to 1

Cutting Speed Feet per Min.	20	30	40	50	60	70	80
Stroke in Inches	Cutting Strokes per Minute						
1	160	240	320	400	480	560	640
2	80	120	160	200	240	280	320
3	53·3	80	107	133	160	186·6	213·3
4	40·0	60	80	100	120	140	160
5	32·0	48	64	80	96	112	128
6	26·7	40	53·3	66·7	80	93·3	106·6
7	22·9	34·3	45·7	57·1	68·5	80·0	91·1
8	20·0	30·0	40·0	50·0	60·0	70·0	80·0
9	17·8	26·7	35·6	44·4	53·3	62·2	71·1
10	16·0	24·0	32·0	40·0	48·0	56·0	64·0
11	14·5	21·8	29·1	36·4	43·1	51·0	58·3
12	13·3	20·0	26·7	33·3	40·0	46·7	53·4
13	12·3	18·5	24·6	30·8	36·9	43·0	49·1
14	11·4	17·1	22·9	28·6	34·4	40·2	46·0
15	10·7	16·0	21·3	20·7	32·0	37·3	42·6
16	10·0	15·0	20·0	25·0	30·0	35·0	40·0
17	9·4	14·1	18·8	23·5	28·2	32·9	37·6
18	8·9	13·3	17·8	22·2	26·7	31·2	35·7
19	8·4	12·6	16·8	21·0	25·6	30·2	34·8
20	8·0	12·0	16·0	20·0	24·0	28·0	32·0
21	7·6	11·4	15·3	19·0	22·8	26·7	30·5
22	7·3	10·9	14·6	18·2	21·8	25·5	29·0
23	6·9	10·4	13·9	17·4	20·8	24·4	27·8
24	6·7	10·0	13·3	16·7	20·0	23·3	26·7
25	6·4	9·6	12·8	16·0	19·2	22·4	25·6
26	6·2	9·2	12·3	15·4	18·5	21·5	24·6
27	5·9	8·9	11·9	14·8	17·8	20·7	23·7
28	5·7	8·6	11·4	14·3	17·2	20·0	22·8
29	5·5	8·3	11·0	13·8	16·6	19·3	22·0
30	5·3	8·0	10·7	13·3	16·0	18·7	21·3
Cutting Factors	160	240	320	400	480	560	640

Explanatory Notes for Determination of Machine Speed (*Table XXIII*)

Each minute of machine time is divided into two parts, one of which is devoted to actual cutting of the material, and the other to the return of the cutting head in preparation for the next cutting stroke.

The magnitude of the cutting portion is derived thus—

$$\text{Cutting time} = \frac{\text{Proportion of time spent in cutting}}{\left(\begin{array}{l}\text{Proportion of time spent in cutting}\\ + \text{Proportion of time spent in return}\end{array}\right)} \times \text{Unit time}$$

and for a machine with cutting/return ratio of 2 . 1 this gives—

$$\text{Cutting time} = \frac{2}{2+1} \times \text{Unit time} = \frac{2}{3} \times 60\ \text{sec.} = 40\ \text{sec.}$$

To give any predetermined cutting speed the machine must be adjusted to give a certain number of cutting strokes per minute, and this number of strokes is arrived at by use of a cutting factor.

This cutting factor actually represents the amount of cutting performed *per minute of machine time*, and is arrived at thus—

$$\text{Factor} = \frac{\underset{\text{(inches/minute)}}{\text{Cutting speed required}} \times \underset{\text{(seconds)}}{\text{Cutting time}}}{\text{Unit time (60 sec.)}} = \text{(say)}\ \frac{(30 \times 12) \times 40}{60} = 240\ \text{in.}$$

From this figure the number of cutting strokes per minute is given by—

$$\frac{\text{Cutting factor}}{\underset{\text{(inches)}}{\text{Length of stroke}}} = \text{(say)}\ \frac{240}{20} = 12\ \text{strokes/min}$$

Specific Example

Suppose an item is to be shaped and that a stroke of 10 in. is required with a width to be traversed by the tool of 6 in., the cutting speed to be 30 ft. per minute, and the feeds per inch to be 30. Let it be assumed that only one traverse of the tool is necessary. Then from the table it will be seen that the machine must be adjusted to give a speed of 24 cutting strokes per minute.

The total number of cutting strokes is shown by

$$\text{Feeds per inch} \times \text{width to be traversed}$$
$$= 30 \times 6 = 180\ \text{strokes}$$

and the actual cutting time for the job is, therefore,

$$\frac{\text{Total number of cutting strokes required}}{\text{Number of cutting strokes per minute}} = \frac{180}{24} = 7{\cdot}5\ \text{min.}$$

Date

APPLICATION FOR AUTHORITY FOR VARIATION FROM STANDARD PRACTICE OF MANUFACTURE

Order No Estimate No Shop No

Standard Operation Ident No Basis Time

Proposed Operation Basis Time

Reason for Variation

To apply on $\frac{\text{This}}{\text{Future}}$ Order

Foreman

Authorized Production Manager Date

FIG 283 AUTHORITY FOR DEPARTURE FROM STANDARD PRACTICE

TABLE XXIV

SPEEDS AND FEEDS FOR DRILLING
HIGH-SPEED DRILLS

Diam. of Drill	Class of Material			
	Brass			
	120 Feet per Minute			
	R.P.M.	Feed per Revolution	Feeds per Inch	Penetration per Minute
1/8	3667	0·003	333	11·0
3/16	2445	0·004	250	9·8
1/4	1833	0·005	200	9·2
5/16	1467	0·006	167	8·8
3/8	1222	0·007	143	8·6
7/16	1048	0·008	125	8·4
1/2	917	0·009	111	8·3
5/8	733	0·010	100	7·3
3/4	611	0·011	91	6·7
7/8	524	0·012	83	6·3
1	458	0·013	77	6·0
1 1/8	407	0·014	71	5·7
1 1/4	367	0·015	67	5·5
1 3/8	333	0·016	63	5·3
1 1/2	306	0·016	63	4·9
1 5/8	282	0·016	63	4·5
1 3/4	262	0·016	63	4·2
1 7/8	244	0·016	63	3·9
2	229	0 016	63	3·7
2 1/4	204	0·016	63	3·3
2 1/2	183	0·016	63	2·9

Explanatory Notes to Table XXIV

Thus, if a hole of, say, 1 in. diameter is to be drilled to a depth of 1½ in., the time required per hole for cutting is determined by

$$\frac{\text{Depth of hole—inches}}{\text{Penetration—inches per minute (from Table)}}$$

$$= \frac{1\cdot5}{6} = 0\cdot25 \text{ min.}$$

Departure from Standard Practice

If for any reason the shop supervisory staff desire to depart from the practice laid down, application to do so should be made by them on a form of the type shown in Fig. 283. The reasons advanced may be (1) lack of correct material, (2) absence of operator with the agreed rate, (3) breakdown of machine, or (4) urgency of work. In all cases authority for the departure from the standard practice schedule should first be obtained through the medium of the production engineer or his responsible assistant.

Personnel Requirements

Lastly, a word about the personnel of the planning office. The staff will comprise both technical and clerical grades. If the planning is to be successful the technical staff must of necessity be individuals with a very complete practical knowledge of the equipment available, as well as of its capacity and relative efficiency. The clerical requirements call for one or two key men, in addition to whom girl clerks and typists whose work can be consistently relied upon (thus avoiding a large amount of checking) will be adequate.

CHAPTER XXIII

PROGRESSING AND SCHEDULING

Relationship of Progressing to Scheduling

SYSTEMATIC progressing is synonymous with intelligent scheduling. Expressed in another way, systematic progressing for all productive activities of a factory can only be carried out by the adoption of an all-embracing system of scheduling.

Perhaps nowhere in the concern does one experience the pulsating activities, with which every progressive factory abounds, to a greater degree than when directly associated with the progress office. Progressing should, however, be carried out methodically, and the progressmen should never race round the works in a haphazard "hit or miss" manner to ascertain whether this or that is done or is in hand, the greater part of the information gleaned being recorded only in their own minds. Nor should progressing become a matter of habitually instructing foremen to put work in hand immediately, as such a course must inevitably be taken at the expense of other work, which it must be assumed was only commenced just soon enough to ensure economic delivery. Neither of these is progressing. Rather are they conclusive proof that the organization leaves a good deal to be desired.

Progressing of work should mean the carrying out of a considered, predetermined plan, based on previous experience of similar work, or on an intelligent estimate of what is involved, having regard to promised delivery dates. There are many different ways in which work can be satisfactorily scheduled. These include the use of Gantt charts, progress boards, and progress "slide rules," all of which have their merits.

Gantt Charts

Brief reference was made in Chapter I to the advantages to be derived from the proper use of charts and graphs. The Gantt type of chart was introduced by Mr. Henry L. Gantt, one of the pioneers in the development of the science of management. It is probably the most widely used of all charts, as its principles can be applied to any human activity. Broadly speaking, it falls into four classes as follows: (1) load charts, (2) progress charts, (3) layout charts, and (4) man and machine record charts.

In all cases a division of space represents both an amount of time and an amount of work to be done in that time, and lines drawn horizontally through that space show the relation of the amount of work actually done in that time to the amount scheduled. This is the distinctive feature of the Gantt chart. Symbols are used in conjunction with this type of chart, the more important being given in Fig. 284. The size of sheet

THE GANTT CHART
STANDARD CODES USED (LETTERS)

Questions to Determine the Chief Reason for Failure to Work to Plan	Code Letters
To be asked in order as shown—	
MACHINE RECORD CHART	
Is the machine ready to run?	R
Is there an order for the machine?	O
Is there material to be worked on?	M
Are there tools?	T
Is there power to run the machines?	P
Is there an operator for the machine?	H
MAN RECORD CHART	
Was machine in good condition?	R
Were tools, fixtures, etc., available and in good condition?	T
Was the operator given proper instructions and sufficient information?	L
Was trouble experienced with material?	M
Was operator recently introduced to the job?	N
Was operator too slow?	U
Was the lot smaller than the anticipated ordering quantity?	S

FIG. 284. SYMBOLS USED IN CONNECTION WITH GANTT CHARTS

recommended for all Gantt charts is one measuring 16 in. × 10 in.

If we take a specific case and consider a load chart for a group of boring mills in a machine shop, we get the type of chart shown in Fig. 285. The thin horizontal lines denote the actual time when the machines were working. The heavy horizontal line in column 1 represents the total work done by all the mills, whilst each of the other thick lines gives similar information for individual mills.

Next consider the progress chart, Fig. 286. This indicates the progress made in the manufacture of a number of details on a specified date—in this case on 6th May. The symbols ┌ and ┐ show the scheduled commencing and finishing dates respectively.

As a further example of the use to which the Gantt chart may be put, it will be convenient to consider here a machine record chart in which is set out the relation between what is accomplished and what could have been accomplished by the machines in a particular department, as shown clearly in Fig. 287.

The number of main divisions required on a Gantt chart will depend entirely on the type of record, and subdivisions will be dependent on the period of time covered, e.g. if one

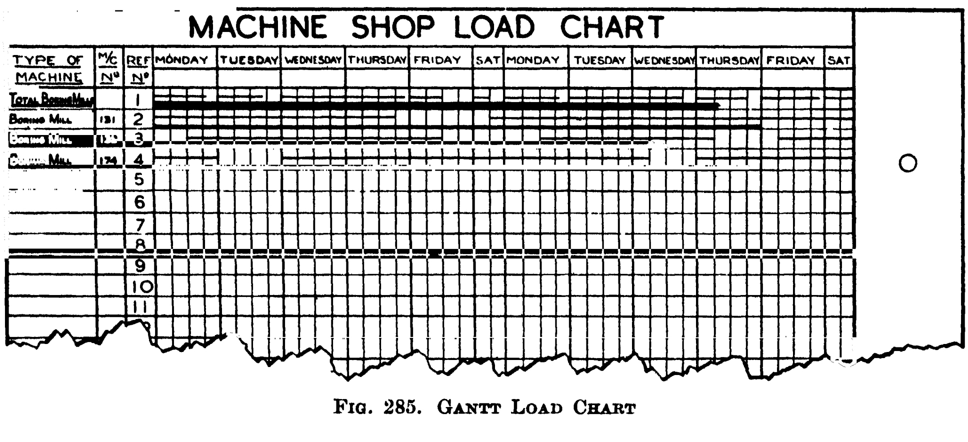


FIG. 285. GANTT LOAD CHART

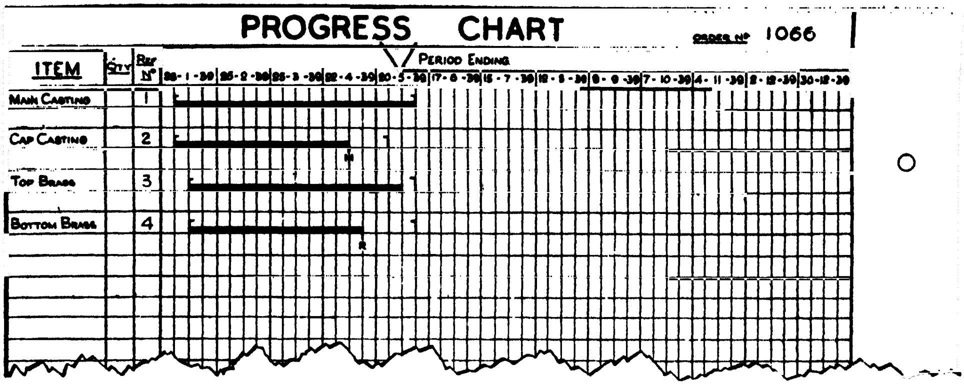


Fig. 286. Gantt Progress Chart

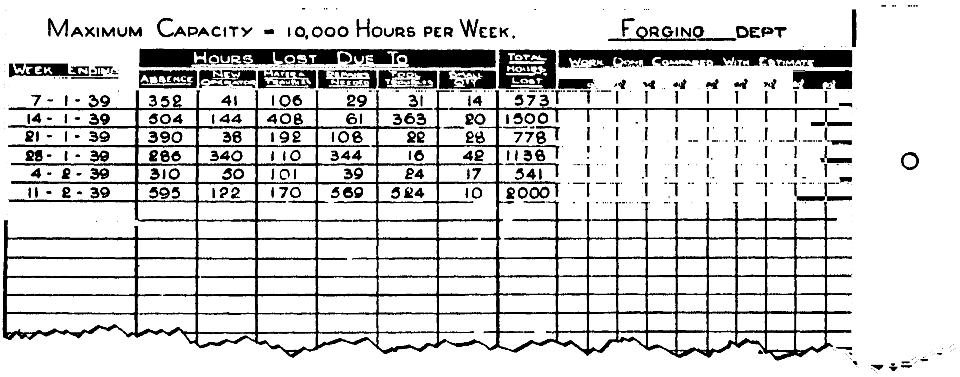


Fig 287. Gantt Machine Record Chart

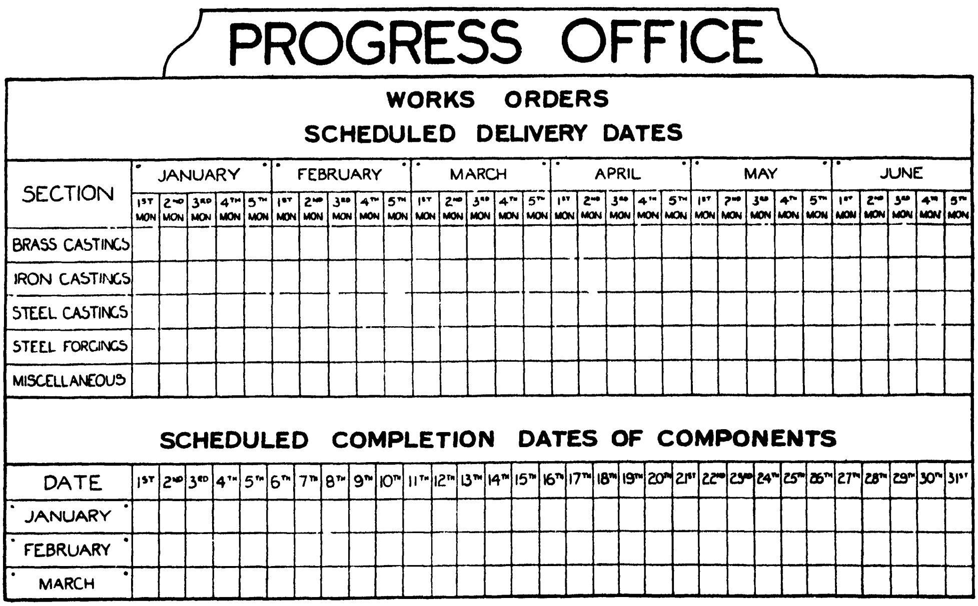


Fig. 288. Progress Board

main division covers one day of 9 hours' duration, then four equal divisions and one division half the width would best meet the case, each of the four divisions representing 2 hours and the smaller division 1 hour.

Progress Boards

Although these may be of many different types, it is suggested that one on the lines indicated in Fig. 288 will have considerable practical value. There should be as many different sections on the board as are necessary in this case five, i.e. "Brass Castings," "Iron Castings," "Steel Castings," "Steel Forgings," and "Miscellaneous."

The top portion of the board covers a period of six months arranged in weeks, and the bottom portion three months arranged in days, a loose plate bearing the name of the month being used so that it may be reversed and a later month indicated. Supposing that thirty sets of steel castings are required at the rate of five sets every four weeks, then six cards, each about 2 in. square, should be made out giving brief particulars of the order and the date required for five sets, the cards being placed on the hooks corresponding to the dates on the cards. In this way nothing of importance is overlooked, irrespective of whether it is to be manufactured in the works or purchased from the trade.

If, when the scheduled date is to hand, the castings are still outstanding, the card should be removed and placed at the bottom of the board on the hook corresponding to the actual day when the castings were anticipated as indicated on the card. The lower portion of the progress board can also be used effectively as a reminder of any verbal arrangement, a card being made out and placed on the division corresponding to the promised delivery date. Thus there is

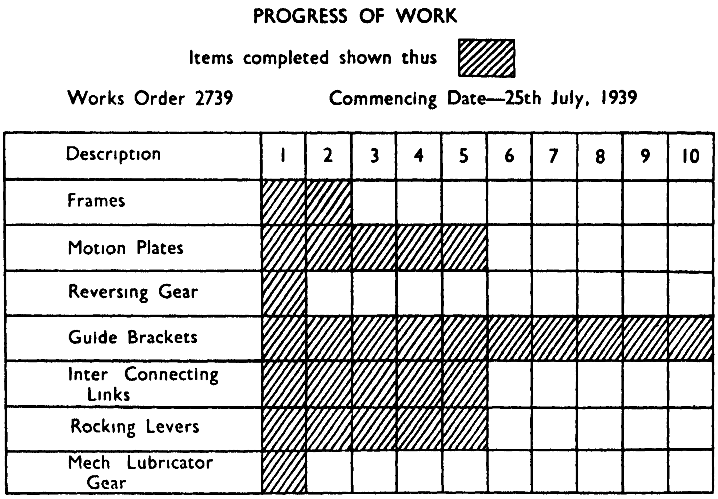


FIG 289 PROGRESS OF WORK CHART

a constant reminder available of what is outstanding, and suitable action may be taken. Even the best man in the progress office cannot remember every decision or promise made! This arrangement has the added advantage of putting on record facts which might be overlooked in the absence of the person or persons originally concerned.

A board of this type is particularly useful where large numbers of works

ERECTION OF DIESEL LOCOMOTIVES

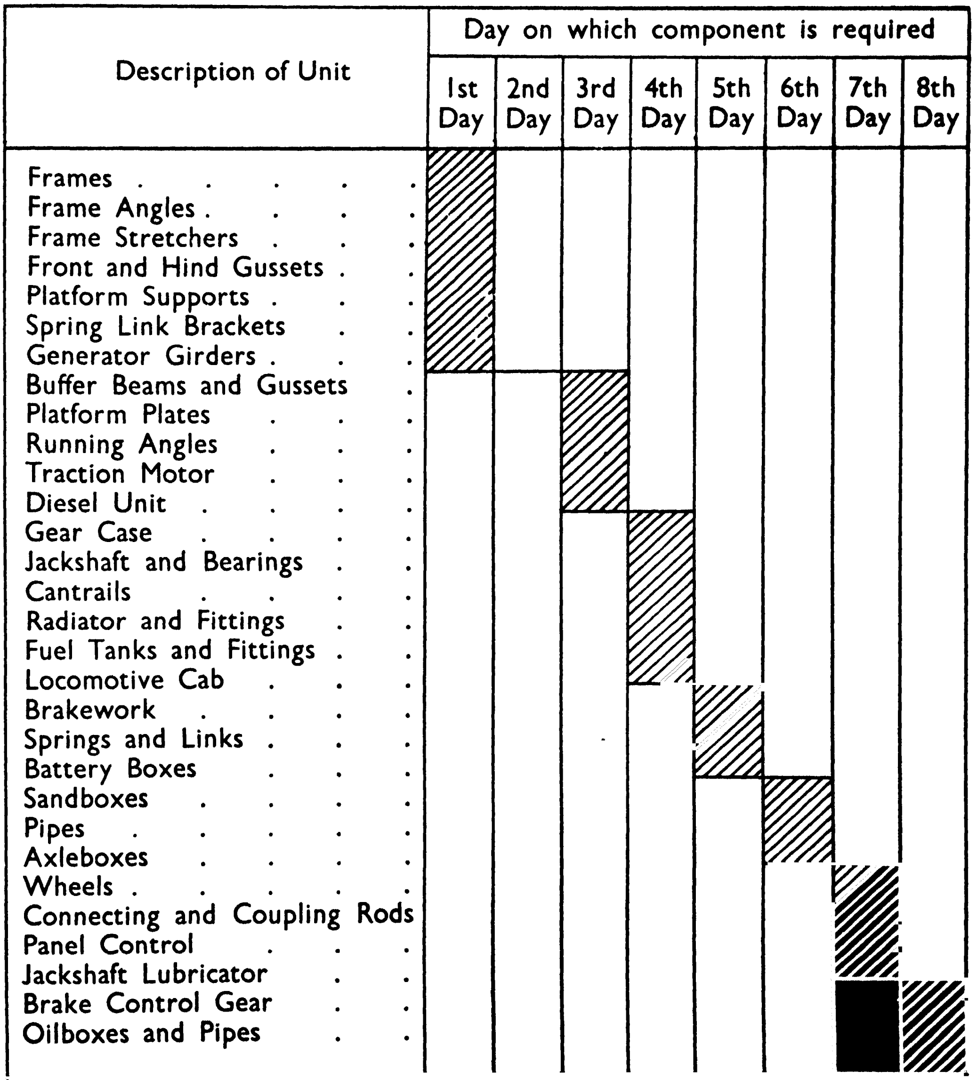


Fig. 290. Progress "Slide Rule"

orders, differing in character, are always in hand.

Progress Charts

Perhaps the most simple form of progress chart is that shown in Fig. 289. It merely shows what has actually been completed. It is very handy for quick reference, and when used in the shops, arrangements can be made for the various section foremen to record the completed work for which they are responsible, the chart in such cases being entered up daily in the chief foreman's office.

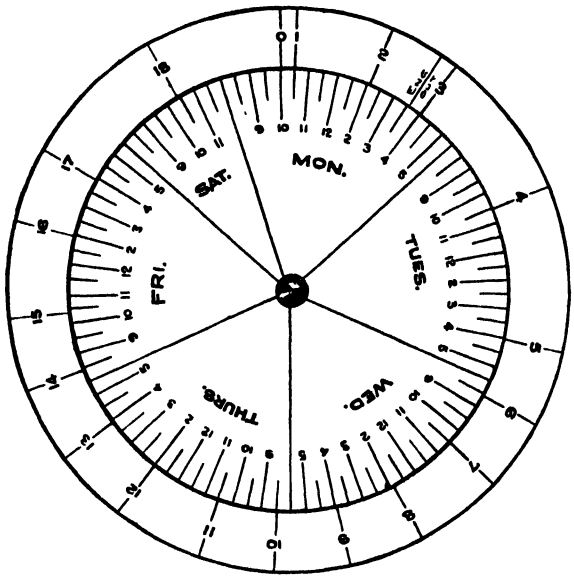


FIG. 291. ROTARY "SLIDE RULE"

Progress "Slide Rules"

Much can be said in favour of the various forms of "slide rule" used in connection with progressing work. Fig. 290, which illustrates the simplest type, shows items required for erection on the first day, the second day, and so on until completion. Where desired, the time of the day can be embodied in the scheme.

A rotary scale, as illustrated in Fig. 291, is sometimes preferred. It consists of two circular discs pivoted at the centre, the smaller of which is capable of being rotated relatively to the other. In the example shown the smaller disc gives the days of the week divided into hours, based on 47 hours per week, and the outer scale gives divisions, numbered 0 to 18, each of which can be considered to represent a definite stage in the assembly of a large marine engine, the distance between the numbers being proportional to the time to be spent upon each stage of erection. Thus, supposing erection commences on Monday at 10 a.m., the inner disc should be set so that Monday at 10 a.m. coincides with the zero point on the outer disc. It can then be seen that Stage 1 should be completed on Monday by 10.30 a.m., Stage 2 by 2 p.m., Stage 3 by 4 p.m., Stage 4 by 10.30 a.m. on Tuesday, and so on, the engine being finally completed (shown as "Engine Out") on the following Monday at 3.30 p.m.

These "slide rules" can be made suitable for pocket use as well as for shop use.

Method of Recording Completion of Work

One thing is certain—the progress office should work hand in hand with

the production planning office, and they should preferably be located together. If for any reason they are separately controlled it is more important than ever that they should be in the closest proximity. The one is the complement of the other and, even though it may be rightly assumed that there is no overlapping, it is difficult to say where one section begins and the other ends.

The value of this collaboration will be realized if arrangements are made for all wages documents to pass through the production planning office on their return from the shops to the accountant and, therefore, when the work has been actually carried out. If this is done and the particular operations in the operation sheets are marked, it will be possible at any time to see how far any work has progressed. The procedure should be as follows—

All wages tickets should be sorted into works order number and manufacturing identification number order. The counterfoil of each wages ticket should be abstracted from a drawer, in which counterfoils are filed in wages order number, manufacturing identification number and wages ticket number order, and should be paired up with the original ticket. All wages tickets and counterfoils should then be checked and any temporary times entered on the counterfoils, after which the cards should be "franked" and passed on to the wages office for payment to be arranged.

The counterfoils should next be stamped with the "week ending" on which the cards were charged, sorted into order number, manufacturing identification number and operation order, and suitably marked off on the operation sheets, or the standard planning cards, which will then show the progress of the work performed on any article up to date. Finally the counterfoils should be filed away in drawers until the order is closed, when they should be destroyed, the operation sheets being retained as a permanent record. Bearing in mind that the marking must be done currently, as the payment of wages cannot be delayed, it will be seen that the record which is created will prove invaluable both during the current production programme and for reference when drawing up future schedules.

Procedure for Progressing Stores Stock Orders

A stock order is a particular type of works order issued for one or more standardized items to be manufactured in the works and placed in stock. Such stock may be required in connection with a saleable product or for subsequent use in the works. As far as is reasonably practicable, stock orders should be dealt with in date order, adequate and systematic attention thus being given to the stock order position and many delay problems being solved. In the production planning office should be a stock order section which registers and controls all stock orders issued. If, for any reason, the shop or shops involved consider that the quantity ordered on a given stock order is uneconomical from a manufacturing point of view, the stock order should

be returned to the production planning office with a note attached stating that the ordering quantity should be in multiples of a certain minimum number.

It is particularly desirable that on the same day as the stock order is received in the shops the requisitions for the material required should be sent to the storekeeper. If this is not done unnecessary delays may arise in obtaining the material when it is proposed to commence work on the stock order.

A combined planning and progress card (see Fig. 282, Chapter XXII) should be maintained in the production planning office giving a complete record of any particular item. Where it is preferred that requisitions and wages documents should be prepared in the shops, instead of in the production planning office, a duplicate copy of the master card will be required in the shops. Such a card record will prove invaluable in any works' organization, and on the assumption that the planning department staff are located with those of the progressing department, it will be found that the latter will frequently refer to it and by so doing avoid overloading of certain machines or sections.

The procedure which is recommended so far as stock orders are concerned is as follows—

Stock orders in duplicate should be issued by the storekeeper as required, according to the maximum and minimum stock agreed for the particular item involved. The requisitions and wages tickets should be issued to the works by the production planning office within twenty-four hours, the counterfoil copy being retained in the production planning office. In the

DELIVERY NOTE

No.

Shop Date Charge Signature

Material to be delivered to

Catalogue No.	Description	Quantity	Charge on Account							
			Tons	C.	Q.	lb.	Rate	£	s.	d.

Quantity outstanding to complete order

Date received in store

Received by

Fig. 292. Material Delivery Note

event of a stock order requiring any alteration it should be returned to the production planning office, which office will in turn pass it back to the storekeeper. In no circumstances should an alteration or addition be made by any member of the works' personnel.

Where orders have had work charged to them, but it is not considered by the stores department that the whole or the balance of the deliveries is necessary, these orders should be closed at the deliveries already made into stores. Incomplete articles should be checked with work in progress in the stock order account. The order should then be closed and the disposal of the material, which should agree with the work in progress in the stock account, should be dealt with by the storekeeper. In all cases a delivery note, Fig. 292, which agrees with the quantity being dispatched, should be made out and accompany the material to the stores department. When the stock order is completed the stock order itself should be attached to the final delivery note.

Delivery notes should not be used for passing material from one shop to another; the correct procedure is to attach to the material a label, Fig. 293, which gives the essential particulars. The expeditious handling and completion of stock orders must always be regarded as an important phase of production planning.

Irregular Practices

It is suggested by some that details completed in any one shop can be appropriated by another before being sent into stock. Such a practice has no logical foundation and can never have the support of an intelligent management. Advocates of such malpractices may ask whether it is preferable to have the "paper" side, as it is so often referred to, kept straight or whether it is better to pass work through the shops in a minimum of time. The reply is that both

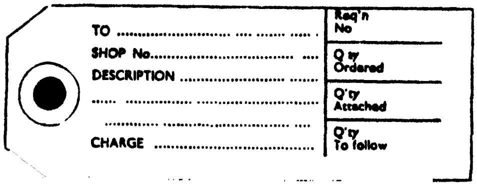


FIG. 293 LABEL FOR ATTACHING TO MATERIAL IN PROGRESS

aspects are equally important and neither should be exploited at the expense of the other. If at any time it can be made a matter of convenience, on the pretext of urgency, to break down an established system, one may wonder whether there is any need for a stores department at all!

The storekeeper places the orders and, as he deals with all demands, it is for him to say where the items should be sent. It is the responsibility of the shops to ensure an adequate supply. It is a shortsighted policy to imagine that short-circuiting always ensures early completion. Such a practice can only lead to chaos and cause additional delays in the works as well as elsewhere, and eventually the works are bound to be the losers. Moreover, it is generally uneconomical to manufacture small quantities to meet immediate requirements. The works should make every endeavour to fulfil their commitments as presented by the

storekeeper. It is not for them to try to do the storekeeper's work. If, when they have put their own house in order, they still have reason to complain, there is a proper channel by which their grievances can be aired and a remedy found.

Flow of Work

Almost invariably it is more economical to bring the work to the operator than for the operator to move to the work. Exception to this rule should only be made in those instances where it is altogether impracticable, as in the construction of a large liner. There is much to be gained by the method suggested, and the modern general tendency in this direction is sufficient proof of its soundness.

Work Points Overloaded

Where a variety of articles or operations has to be dealt with, it is worth while to obtain a large scale plan of the shop and to draw on it, in different colours, the routes taken by each article. If a number of these lines converge at certain machines or other points it may readily prove, if taken in conjunction with the time required for the productive operation, that there is some congestion, and consequent delay, either because the layout requires revision or because additional machines or men are required at these points.

Continuous Working

There is at least one well-known firm which has been running its large factory for 24 hours a day and giving its employees a 6-hour day. It is paying higher wages than the average factory and has greatly increased its sales and net profits. This all tends to prove the profit-making magic of operating machinery for 24 hours a day. There is no other way whereby so much profit can be made in manufacturing.

Everyone knows that the profits of any factory, where expensive plant and machinery are used, depend most of all upon the actual working time of the machines. When the machines work for 144 hours a week, as they do in some factories, higher wages are frequently possible. When the machines work for only 47 hours a week, as is more usual, the cost of production is inevitably higher.

A machine can do a certain amount of work, and the sooner it does it the better. That is a rule of manufacturing which is worthy of consideration. There is one proviso—namely, that partial working of a shop or department does not necessarily result in economical working.

Space Requirements

Where the erection of large units is carried out requiring a definite allocation of space for each unit, it is possible to introduce a simple formula consisting of three variables, so that if any two of the variable elements are decided upon the third can always be ascertained. Thus, if

$$\begin{aligned} \text{No. of Pits} \quad & N \\ \text{Weekly Output} &= O \\ \text{Time (in weeks) to be taken per unit} &= T \end{aligned}$$

$$\text{then } T = \frac{N}{O} \text{ weeks}$$

This is an extremely useful formula, and is consequently well worth remembering.

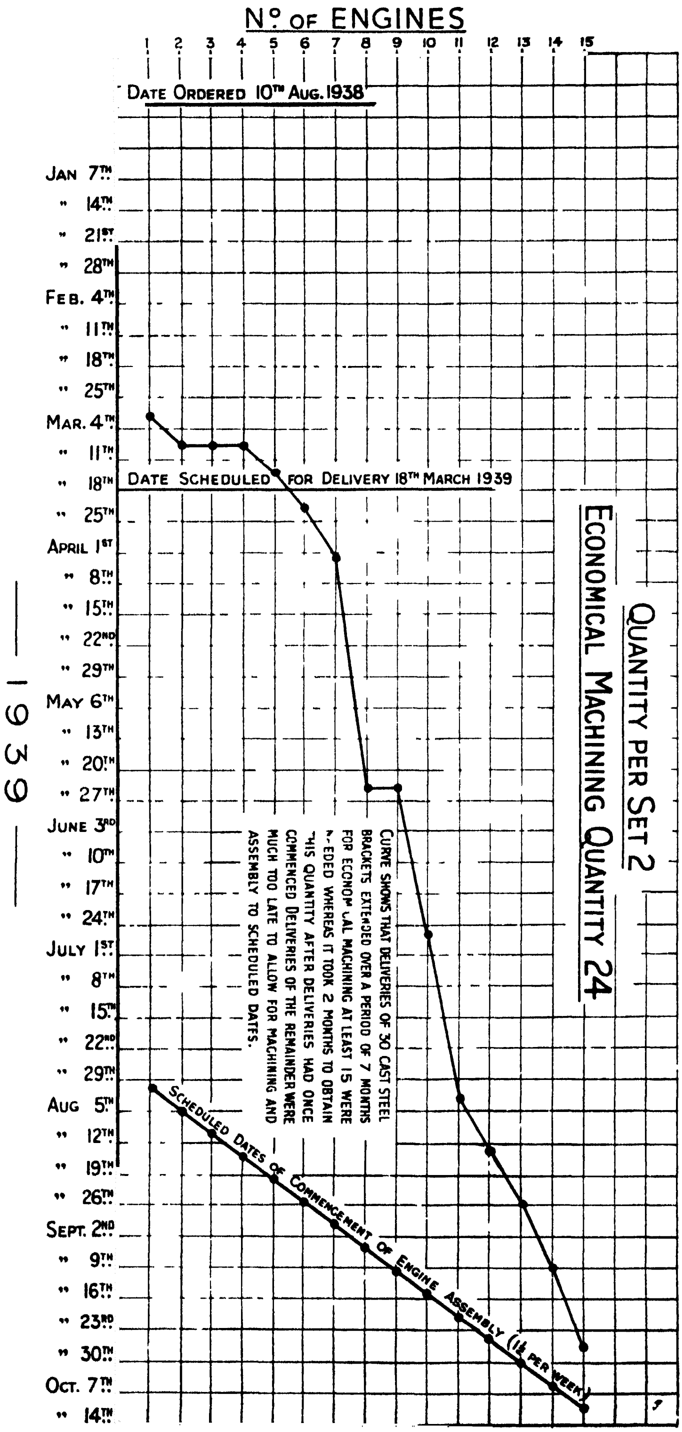


FIG. 294. GRAPH TO DEPICT LATE DELIVERY OF MATERIAL

Late Deliveries of Material

Late deliveries, whether they be due to internal difficulties or mishandling, or whether they involve outside contractors, are always a genuine source of annoyance and frequently result in uneconomic production. Occasional trouble should be overlooked without an "inquest" being held if the reasons given appear to be sound, but if the trouble is the result of repeated failure then it is recommended that a graph, drawn up on the lines shown in Fig. 294, should be prepared and brought to the notice of the production engineer.

Daily Progress Meetings

Progressing and scheduling are definitely managerial functions, and when once a reliable production programme has been drawn up the work of keeping the information up to date is largely clerical. In a large works a maximum, say, of two progressmen, who should be technical staff attached to the progress office, should be sufficient to keep in touch with and co-ordinate the various manufacturing departments.

A short daily meeting, commencing say at 10 a.m., between those most closely concerned with actual production work, has much to commend it. It is important, however, that the number attending should be kept small and that the discussion should not develop into excuses for non-completion of work, but that it should tend to promote a good team spirit as well as to ensure economic production.

Hustle is not work, but the enemy of work.

ARNOLD BENNETT.

CHAPTER XXIV

INDUSTRIAL STANDARDIZATION

Extensive Application

At first the word standardization suggests something which is dull and monotonous and which brings us to a dead low level of uniformity. A little consideration will, however, show that this is a mistaken idea. As a case in point, ordinary 9 in. × 4½ in. × 3 in. bricks have been standardized for generations and yet architects have had it in their power both to offend and to please the eye, depending on whether they have made bad or good use of the bricks in their designs. Furthermore, can anyone believe that the imagination and constructive ability of the consulting engineers responsible for such vast works as the Sydney Harbour Bridge or the Mersey Tunnel has been in the slightest degree adversely affected by such standards as have been produced? There is probably no other industry in which there is so much "working to rules, regulations and standards" as in locomotive construction, yet the professional men in that business continue to design new engines, and their engineering status is not by any means "at a low level of uniformity."

Industrial standardization does indeed cover a very wide field. There is the fixing of dimensions for interchangeability, e.g. the case of the domestic electric light bulb. There is the reduction of diversities in articles intended for one and the same purpose, e.g. the sectional material specifications, and there is the quality of materials, regarding which a great number of national agreements have been reached under the standards organization. Again, there is the question of the performance of machinery, to ascertain, for example, whether a so-called 100 h.p. electric motor will produce the power expected of it. There is also the question of factors of safety in design, construction and installation work, the primary object being the safety of the public and workers by the provision, through nationally agreed standards, of adequate strength and appropriate quality of materials. Considerable work has been carried out on these lines by the Standards Committees, in some cases at the specific request of the Home Office, and with the full concurrence and active support of industry.

Development of the British Standards Institution

In 1900, Mr. H. J. Skelton, engineer and steel merchant, read a paper to the British Iron and Steel Association advocating the reduction and standardization of steel sectional material. In the following year, Sir John Wolfe Barry, impressed by that paper, approached the Council of the Institution of Civil Engineers, and a committee comprising eight leading engineers was appointed. Kindred societies were

approached, viz. the Institution of Mechanical Engineers, the Institution of Naval Architects, the Institution of Electrical Engineers, and the Iron and Steel Institute, and a general committee was formed. This committee appointed a sectional committee, with three sub-committees to deal with sectional materials for use (1) on bridges, (2) on railway carriage underframes, and (3) in shipbuilding and marine engineering. These sub-committees called in representatives of the Admiralty, the Board of Trade, the Classification Societies, steel manufacturers, and independent experts, and, working independently and then jointly, prepared a list of each type of section, numbering in all 166. It was found that the rolls in British steel works approached 300 different sections. Standard test pieces, methods of testing and standard tests were decided upon, and the list was first published in 1903. In 1914, a revision of the specification led to an increase to 174 sections, but after the Great War another revision in 1919 reduced the list to 113.

By 1905 there were thirteen sectional committees, with a large number of sub-committees, totalling some 250 persons. To-day there are over 1000 committees of all kinds consisting of nearly 6000 architects, chemists, engineers and other professional men throughout the country, who give their time and experience freely to this national work.

In 1918, the Engineering Standards Committee was incorporated principally in order to be able to administer a standard mark of the British Engineering Standards Association. In 1929 a Royal Charter was obtained, the scope being unaltered, and the main committee became the council. Later a demand was made for an extension of its scope by the inclusion of the building and chemical industries. Hence a supplementary Charter was obtained in 1931, which enabled the council to carry out the Ottawa decisions and promoted the desire for only one Central Standards Association for each part of the British Empire. It became the British Standards Institution, with a general council and divisional councils for engineering, building and chemical industries, and provision for a textile council.

Objects of the British Standards Institution

The principal objects of the Institution are, in its own words: "To co-ordinate the efforts of producers and users for the improvement, standardization and simplification of engineering and industrial materials. To simplify production and distribution. To eliminate the waste of time and material involved in the production of an unnecessary variety of patterns and sizes of articles for one and the same purpose. To set up standards of quality and dimensions, and promote the general adoption of British Standards.

"In all its endeavours the Institution maintains the community of interest of purchaser and producer. It does not embark on any work without first ascertaining that there is a consensus of opinion in favour of its being

proceeded with, and that it is to fulfil a recognized want. This national work is carried on largely by means of grants received from the Government, professional institutions and industrial and trade organizations, as well as by sales of its publications. The amount derived from these sources is, however, not sufficient, and the Institution has to look to industry as a whole for the further funds necessary to enable it to meet the increasing demands made upon its organization. Membership of the Institution is open to British subjects, companies, technical and trade associations, and local and public authorities. The Institution is not a profit-making concern, its only expenses being staff salaries, office expenses and printing."

The affairs of the Institution are governed by a General Council on which industry is fully represented, and on which are also represented the Board of Trade, the Department of Scientific and Industrial Research, the National Physical Laboratory, the Federation of British Industries and the Association of British Chambers of Commerce. The Institution is in direct touch with the standardizing bodies in foreign countries and participates, directly or indirectly, in the work of international standardization as and when industry so desires. A copy of the handbook of the British Standards Institution should be in the hands of all engineers.

Any request for a British Standards Institution specification must come from an authoritative source, must give evidence that the producers and users are prepared to co-operate, and that the necessary funds for carrying out the work are forthcoming. Periodical review and revision is undertaken to prevent crystallization and to keep the work abreast of progress, and no coercion whatever is allowed by one section of the community over another. Thus the principal object of standardization is to discourage the use of varying specifications when one standard specification will serve the purposes to the advantage of industry as a whole. Any individual or group of individuals has the right of appeal to the General Council.

Co-operating Organizations

The Mechanical Industry Committee, under whose supervision many British standards are prepared, consists of representatives of the following Government departments and scientific and industrial organizations—

Admiralty.

Crown Agents for the Colonies.

Department of Scientific and Industrial Research.

High Commissioner for India.

H.M. Office of Works.

Home Office.

Ministry of Transport.

War Office.

Agricultural Engineers and Road Machinery Manufacturers' Association.

British Chemical Plant Manufacturers' Association.

British Electrical and Allied Manufacturers' Association.

British Engineers' Association.

British Iron and Steel Federation.

Institution of Automobile Engineers.

Institution of Gas Engineers.

Institution of Heating and Ventilating Engineers.

Institution of Mechanical Engineers.

Locomotive Manufacturers' Association.

Machine Tool Trades Association.

Railway Companies of Great Britain.

B.S.I. Standards

Up to the present time nearly 1,000 British Standard Specifications have been issued. Nowadays, therefore, those who have the responsibility for selecting the standards to be used in design begin with the great advantage of a wide range of B.S.I. standards which have a general acceptance. These general standards may be supplemented by the particular standards for which business calls. A simple example is that of the ordinary bolt. This may have the head and screw thread complying with a general standard, whilst that portion of the shank which follows between the head and the screw thread may comply with a particular standard. All too frequently experience shows that particular standards are adopted when general standards would fully meet the case at a lower cost.

An excellent application of a general standard is the use of colours for distinguishing pipes, ducts, and cables according to the service to which they are put, details of which are given in Chapter IV.

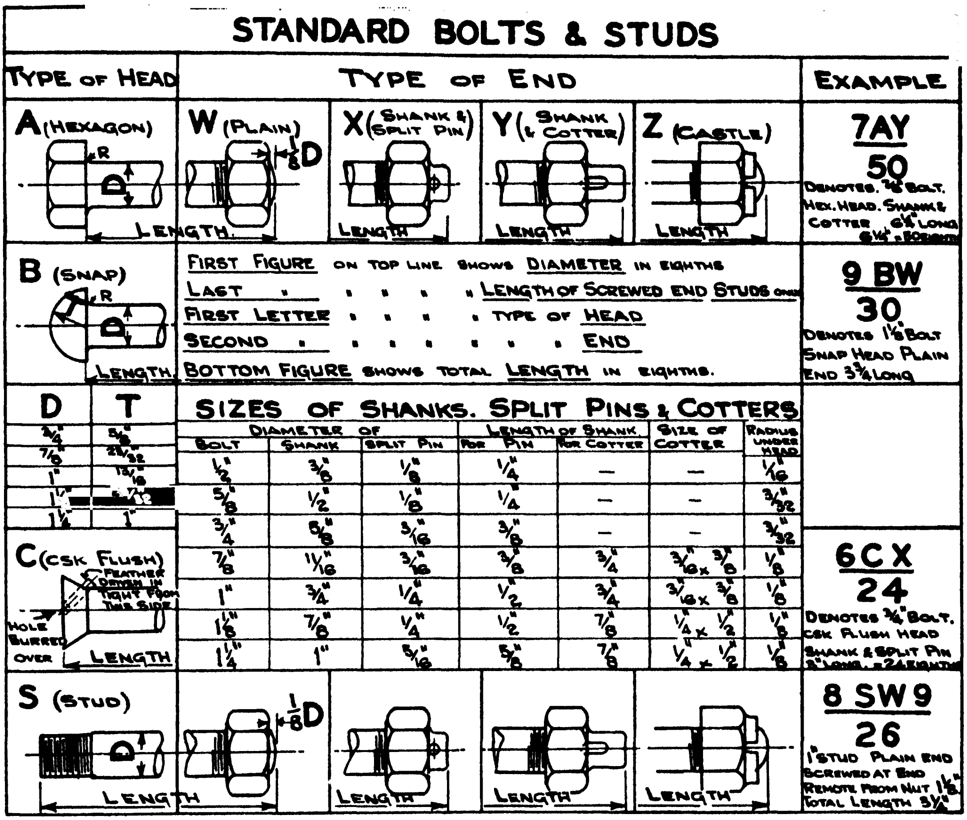
Standardization requires the exercise of constant vigilance both inside and outside the works if the best results are to be obtained. There are, indeed, many trade and individual manufacturers' standards which are not any too well known, and it is good practice to inquire of manufacturers whether such standards exist before inviting quotations.

Standard Design

Apart from the question of whether the standards to be adopted are general or particular, the majority of engineering works use many standardized details of their own design, and these standard details are coded and classified in such a way as to be readily available for the use of their draughtsmen, as well as of their shop staff. Fig. 295 is suggested as providing a suitable chart for standard bolts, these to be referred to on all drawings in the manner shown. Copies of this chart should be framed and hung in prominent positions in the shops. Standard details may refer to single components such as screws and bushes, or to assembly units such as ball races and lubricators, or even more specialized details such as carburettors, particularly when purchased from an outside source.

As well as in the design of the product, standardization may have equally valuable application in such matters as tool design, administration routine, printed forms, and containers. Fig. 296 suggests items suitable for consideration as office standards, whilst Fig 297 is itself a standard form for inter-departmental use. Even the planning of individual responsibilities may be recognized as a form of standardization, a standard being in essence a specification or definition of an activity or of an article. The

frequency with which the standard is put into practice is a different matter and should never be confused with the formulation of a standard in the first instance. Obviously the more frequently the standard is used the greater the resultant benefit.



D	T
3/4"	5/8"
7/8"	23/32
1"	13/16
1 1/8"	[illegible]
1 1/4	1"

Diameter of Bolt	Diameter of Shank	Diameter of Split Pin	Length of Shank for Pin	Length of Shank for Cotter	Size of Cotter	Radius under Head
1/2"	3/8"	1/8"	1/4"	—	—	1/16
5/8	1/2"	1/8"	1/4	—	—	3/32
3/4"	5/8"	3/16	3/8"	—	—	3/32
7/8	11/16"	3/16	3/8	3/4"	3/16" x 3/8"	1/8
1"	3/4"	1/4	1/2	3/4	3/16 x 3/8	1/8
1 1/8"	7/8"	1/4"	1/2	7/8	1/4 x 1/2	1/8
1 1/4"	1"	5/16"	5/8"	7/8	1/4 x 1/2	1/8

FIG. 295. CHART FOR CODING OF SUGGESTED STANDARD BOLTS

Standard Practice Instructions

It is an accepted fact that many achievements in ancient civilization were lost because of the absence of the means of recording. The same often applies to-day in industry under a "rule of thumb" management, the action on a problem only being secured when occasion arises. On each occasion it is thought out separately, with various interpretations of methods according to the individual. Accordingly, standard practice instructions in any concern indicate a tendency on the part of executives to think clearly and with some definite plan. They have many applications, some of which are—

(1) Giving orders through proper channels.

OFFICE STANDARDS

PRINTING STANDARDS

FORMS

Standardization of forms as to size, weight, colour, stock, typography, and manufacture. Securing approvals of revisions and new forms to comply with set standards.

MASTER SET

Control of master set of files and data cards covering all forms, and keeping same complete with latest available information.

METHOD STANDARDS

FILING

Designing systems for special requirements. Standardization and centralization. Surveys, layouts, recommendations. Indexing, filing, and re-filing.

RECORD DESTRUCTION

Surveys of record storage and organizing record destruction "drives" to offset requisitions and additional space and storage equipment.

OFFICE SPACE ASSIGNMENT

Analysis of space requirements. Planning details of moving offices, with recommendations to departments concerned. Co-ordination of departmental efforts in space assignments

CORRESPONDENCE

Restricting to essentials; uniformity, rules for handling; reducing present cost of correspondence and documents by introduction of labour-saving devices.

EQUIPMENT STANDARDS

OFFICE MACHINES

Standardization; functional record of machines; guarantees; durability, portability, repair service, maintenance costs, production capacity. Selecting least expensive machines and appliances best suited to each type of work.

FURNITURE

Standardization. Selecting least expensive furniture best suited to each type of work.

STATIONERY

Making tests of various selected items of stationery to definite standards in co-operation with the Purchasing Department

FIG. 296. CHART SHOWING ITEMS SUITABLE FOR CONSIDERATION AS OFFICE STANDARDS

Your Ref. Office,
My Ref. 19

Subject

(See paragraph No. below)

1	I enclose as requested
2	I have not received your return as above for Please send on all speed.
3	Please return enclosed with your { remarks. / report.
4	Please note { for your information and attention / and return papers
5	I have perused and herewith return your papers with particulars as requested ....
6	Have you yet received
7	You may file papers.
8	Please keep on hand for the present.
9	Your letter of has attention.
10	Please reply to my letter of
11	The return as above is NIL.
12	

Mr.

(Signed)

FIG. 297. STANDARD "OMNIBUS" FORM FOR INTER-DEPARTMENTAL USE

(2) Indicating lines of authority.

(3) Describing methods of procedure (inter-relationship of two or more persons).

(4) Calling attention to changed conditions (transference of functions, etc.).

(5) Defining responsibilities (general and particular).

Their advantages are perhaps even more concrete in character.

(1) They are not likely to be misunderstood or forgotten.

(2) They fix the responsibility for mistakes.

(3) They clarify ideas of those giving orders and expedite routine.

(4) They facilitate gradual improvement in method.

(5) They constitute a ready reference file of managerial and executive decisions.

Visits to Works

To an organizer method is essential, and method is almost another word for standardization. A simple example is the showing of visitors round the works. It is very desirable, in a large factory, that visits should be standardized according to a predetermined scheme. In the first place arrows should be painted on the walls to denote clearly the standard route to be taken by the guides. Standard instructions to the latter might read as follows—

INSTRUCTIONS TO GUIDES

1. All guides should obtain from the Personnel Department an official guide badge to be worn by them throughout the tour, also particulars of the route and timings to be followed, and a list of items of interest in each shop to be visited. A copy of this list should be handed to each member in the party before the tour commences.

2. As soon as a party arrives on the premises, the guides should arrange for the individuals to be formed into groups for which indicator stands are provided, and by so doing obviate the straggling of members of the party, as well as ensuring that individuals making up the groups remain in their places until ready to start the tour.

3. Prior to the commencement of the tour the senior guide should arrange for the promoter of the visiting party to sign the Visitors' Book, which is kept in the Inquiry Office

4. The standard route, which is clearly indicated by arrows, avoids unnecessary walking and is not to be deviated from unless special instructions are given beforehand. Two hours is the time allowed except where otherwise instructed, and every effort should be made to keep to the times given.

5. Special care must be taken to ensure that no member of a party wanders into dangerous places, e.g. walks under travelling cranes when loads are being carried, or enters welding cubicles without the prior knowledge of the welder, and it is the responsibility of the guide at the rear of each group to see that the whole group is kept together, and that individuals are not allowed to detach themselves from the group.

6. Throughout the tour the guides will be responsible for the conduct of the party, care being taken to ensure that the visitors are not allowed to interfere with the work in progress.

7. At the conclusion of the tour one of the guides should return the guide badges to the Personnel Department.

8. Guides should take every opportunity of making the visits as interesting as possible by explaining to the parties, in as much detail as time permits, the principal processes followed in the workshops.

9. Whenever in doubt guides should appeal to the appropriate shop foreman for information.

10. If, for any reason, a party has arrived late, or falls behind schedule during the tour, thus making it necessary to shorten the itinerary, the Foundry and/or the Forge will have to be omitted from the tour.

Secondly, a fixed commencing time should be arranged for the morning

or the afternoon as the case may be. If this is supplemented by a standard time-table, an example of which is given in Fig. 298, and a copy is sent to all the shops concerned, it will materially assist in the arrangements being carried out according to plan, and will ensure that the visitors, any or all of whom may be potential customers, will leave the works fully repaid by their visit.

The party, consisting of approximately 80, is due at the Works (Main Entrance), at
The leader is Mr.

The party is to be assembled outside the General Offices and is to be divided into 4 groups numbered 1 to 4, each approximating 20 persons, with two guides to each group.

The tour will commence at 2.30 p.m., and will be in accordance with the following itinerary –

Department	Time Allotted	Group			
		1	2	3	4
	min.	p.m.	p.m.	p.m.	p.m.
Forge	10	2.30	3.40	4.5	3.30
Flanging	10	2.40	3.50	4.15	3.20
Welding	5	2.50	4.0	4.25	3.15
Pattern	5	2.55	4.5	2.30	3.10
Fitting	10	3. 0	4.10	2.35	3.0
Electric	10	3.10	4.20	2.45	2.50
Steel Foundry	10	3.20	2.30	2.55	2.40
Iron Foundry	10	3.30	2.40	3.5	2.30
Machine	15	3.40	2.50	3.15	4.15
Assembly	15	3.55	3.5	3.30	4.0
Test	10	4.10	3.20	3.45	3.50
Finishing	10	4.20	3.30	3.55	3.40

All groups will reassemble outside the General Offices at 4.30 p.m. and will leave the Works together.

FIG. 298. STANDARD TIME-TABLE FOR VISIT TO WORKS

Reasons for Occasional Failure

Where standard practice instructions occasionally fail in practice, it is due to one of the following reasons—

(1) *Too many instructions.* An instruction numbered, say 2511, is likely to be regarded lightly since it is quite impossible to keep such a mass of information in mind. In some cases the sources of orders are excessive. It is a hopeless state of affairs to have two conflicting orders or instructions both intended to be binding.

(2) *Insufficient care in preparation.* The use of obscure terminology or failure to visualize all implications involved causes need for amendment. Standard practice instructions should be explicit and correct when first issued.

(8) *Preparation by minor executives.* If instructions are prepared by individuals occupying minor positions in the organization, they defeat their own purpose, viz. that of promoting high executive direction.

No one should know better than the individual requesting it, what information is required. It is for him, therefore, to set out his questions or give his headings in a clear, intelligible manner making it impossible for anyone to

No

19

PLEASE GIVE THE INFORMATION ASKED FOR BELOW

Reference to Requisition or Other Return	Particulars	Question	Reply
SHOP NO.			

FIG. 299 PRO FORMA FOR INTERNAL INQUIRIES

Adoption of a Pro Forma

One of the most useful applications of standardization is the use of a *pro forma* whenever information of a similar character is required from various sources, whether this be inside or outside the factory.

answer him wrongly or even in a manner which is likely to cause unnecessary work or result in further inquiries. For internal inquiries of a general character a stereotyped form similar to that shown in Fig. 299 can be advantageously used.

CHAPTER XXV

RESEARCH AND TECHNICAL DEVELOPMENT

Aims of a Research Department

THE object of a research department is to assist in increasing the net revenue of a firm in relation to its capital outlay. It may achieve this result either directly, by suggesting means of effecting savings in the overhead expenses, or indirectly by assisting in the development of a better yet cheaper product. However the result is obtained, the research department should perform at least six major functions, these being -

(1) To discover and define problems in which scientific research can assist.

(2) To provide means, either internally or externally, for carrying out such scientific research.

(3) To act as scientific consultants to each department.

(4) To keep each department in touch with scientific developments relative to its activities.

(5) To draw up working instructions concerning the product for the guidance of the customer.

(6) To investigate cases of failure and suggest means of preventing a recurrence.

Formerly, industry and manufacturing grew more or less naturally without scientific planning. Someone had an idea and put it into use. Someone else improved upon it, and industry progressed slowly by the trial-and-error method, which is just another way of saying that practical men profited by the mistakes they made. Consequently the inauguration of research and development departments was justified, maintaining a staff of research and development engineers, chemists, and metallurgists. Research finds things out. Development applies that information.

The research department should set an example to other departments by attacking the practice of depending upon unsupported opinions. It should be made clear to all that the conclusions of the department are the result of a careful consideration of facts, which should be enumerated and discussed, if necessary, so that a clear understanding may be reached. Opinions, like definitions, are apt to remain the same long after the facts from which they originated have changed, and a close watch should be maintained for the beginning of their obsolescence or unsoundness. It is much safer and wiser for the research department to assume that, although certain conclusions at present appear to be sound, it is always possible for new conditions and new elements to arise which may make their modification necessary. On the other hand, such a department must always guard against the danger of under-rating the merits of existing methods. It should in fact be anxious to support long-established practices if actual facts

prove them to be fundamentally sound.

In an established industry the work

Date 19

EXPERIMENTS

TRIALS OF PROPRIETARY ARTICLES, MATERIALS, ETC.

I wish to suggest that the following experiment or trial be carried out

(1) TITLE:

(2) ORIGIN: (If originating from Stores Superintendent, attach copy of letter.)

(3) MANUFACTURER AND COMPARATIVE PRICES: (In the case of trials of Proprietary Articles, Materials, etc.)

Manufacturer	Price	Present Contractors	Price

(4) BRIEF DETAILS OF TRIAL OR EXPERIMENT, AND ESTIMATED TIME REQUIRED TO COMPLETE. (Attach sketch, if necessary.)

If you agree to this proposal, I shall be pleased to receive your approval.

FIG. 300. FORM TO BE USED FOR THE INITIATION OF AN EXPERIMENT

of the research department is essentially of an advisory nature, whereas in many of the newer industries, e.g. the wireless industry, it is largely in the research department that the products of the industry are conceived. It is necessary that as far as possible results should be set off against expenditure, otherwise there may be a tendency to investigate wastefully. Figs. 300 and 301 typify the forms which should be used for the initiation and conclusion respectively

Date 19

EXPERIMENTS

TRIALS OF PROPRIETARY ARTICLES, MATERIALS, ETC.

Experiment Reference No.

(1) TITLE OF EXPERIMENT:

(2) BRIEF SUMMARY OF RESULTS:

(3) ACTION TAKEN:

(4) DATE EXPERIMENT COMPLETED

FIG. 301. FORM TO BE USED AT THE CONCLUSION OF AN EXPERIMENT

of any authorized experiment. These may be supplemented by a six-monthly progress report.

It may be wondered why the personnel of a separate research department should be more fitted to perform these functions than those who are in daily contact with the problems arising. Let us examine the position. Whilst it is true that the investigator often commences with the apparent disadvantage of not being closely familiar with all the details of the

problem to be considered, he can rightly claim certain definite advantages. He has had a specialized training in the scientific analysis of observed facts, he is expert in the technique of measurement, is familiar with outside sources of knowledge, is free from administrative and routine duties, and he has time to study each problem on its merits.

Government Department of Scientific and Industrial Research

Until comparatively recently there was none of the co-operation between industry and science which is apparent to-day. During the Great War the technical man and the man of science were brought into close co-operation in order to meet the problems of supplying munitions and materials of war. Research workers, drawn from the universities, were employed side by side with practical men, to work out their common problems. The results surpassed all expectations. Means were found of replacing supplies of raw materials suddenly cut off, and substitutes were found for semi-manufactured articles and finished products essential to industry and the fighting services.

In the midst of the distractions of war, the British Government determined, with remarkable foresight, that the close link between science and industry which the common danger was forging should not be broken in the difficult times which were likely to follow the cessation of hostilities. Accordingly, in 1915, the Committee of the Privy Council for Scientific and Industrial Research was formed, and an organized attempt was thus begun to help industry generally through the application of science. In two years the new organization developed into the Department of Scientific and Industrial Research. Early in its history the new Department assumed the control of the National Physical Laboratory, which now occupies buildings covering an area of over 50 acres, with a staff of 600 constantly engaged in accurate testing for industry or in research of various kinds.

Equally important is the provision made at other laboratories established under the Department for research in the national interest. At the Fuel Research Station the problems of the better utilization of coal and its conversion into other forms of fuel are studied. Elsewhere, the problems of the transport and storage of foodstuffs are investigated. In this work the fundamentals of a new branch of science, called "biological engineering," have been evolved. As a result new methods for storing meat, fish, and fruit have been developed, from which the consumer, the home-grower and the shipper are each reaping benefit. At the Building Research Station problems of heating and ventilation, noise in buildings, fire resistance and new methods of construction, such as reinforced concrete and steel-frame building, are all studied in the light of facts revealed by research. The Department has, however, had to do more than this. It has had to bring help, which only scientific knowledge can give, within the reach of every manufacturing industry in the country. The big industrial

corporations present no difficulties because, in their own interests, they have been able to provide research organizations closely linked with their industrial machines, but the smaller concerns are differently situated.

As mentioned in Chapter X there are some 145,000 factories in Great Britain, a bare 600 of which employ more than 1000 workers, while over 130,000 factories employ less than 100 workers each. Obviously such firms as the latter could not maintain their own research laboratories and laboratory staff, and to meet the case the Department of Scientific and Industrial Research has a scheme for creating autonomous co-operative research associations in the industries, these associations being financed by the industries themselves and by the State, which contributes in proportion to the amount subscribed by industry. This bold experiment in the organization of research has proved a pronounced success, and twenty such co-operative research associations are now actively functioning with grants from the Department.

It is, of course, impossible to express generally, in terms of money value, the results of research. Frequently the weak links in the chains of production are discovered and strengthened, and altogether the work of the associations helps to improve the quality of goods, eliminates waste and increases the general efficiency of industry.

Research Laboratories and Personnel

Figs. 302 and 303 depict typical research laboratories. The type of equipment used, as well as the layout adopted, will of course depend on the nature of the industry. In all cases, however, it should be of the best if complete confidence in the findings of any investigation or pronouncement is to be ensured. The research engineer, technologist, metallurgist and chemist should preferably each possess a science degree in the subjects relevant to his own particular sphere. Nowhere in industry is this more important. Their reports should always be strictly and consistently confined to facts; they should be adequate and yet not cumbersome.

Classification of Problems

Generally, a research department should comprise one or all of the following distinct sections, the size of each depending upon the nature of the industry.

Section 1. Engineering.
Section 2. Metallurgy.
Section 3. Chemistry.
Section 4. Textiles.

Taking a few examples at random, relevant to these sections, we have the following classes of problems to investigate.

Section 1. The systematic examination of mechanical fractures may reveal a preponderance or otherwise of failures due either to material or design. Again, a survey of the temperature, air pressure, and ventilating conditions in the offices and workshops may prove advantageous from the point of view of economical working and the comfort of the occupants.

Section 2. This section includes the important though widely differing

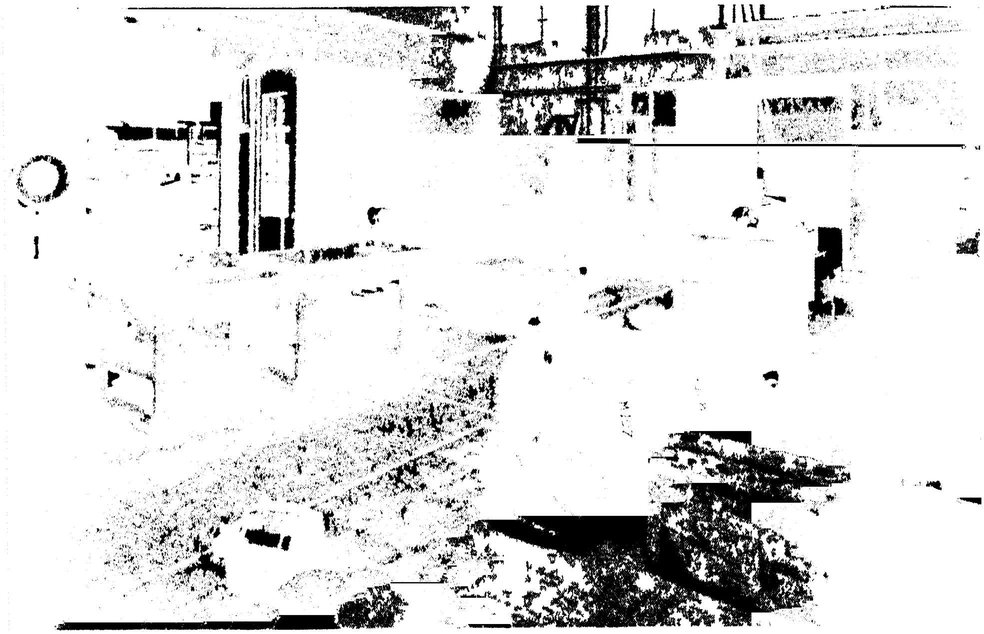


FIG. 302. ENGINEERING RESEARCH LABORATORY

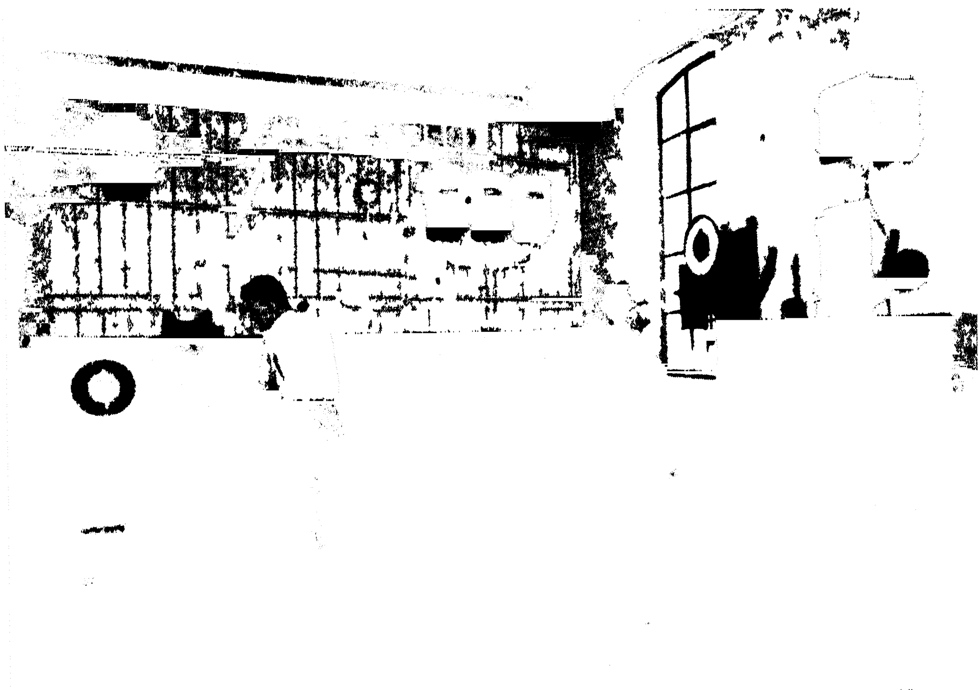


FIG. 303. STRENGTH TEST OF INDIVIDUAL CORDS IN TYRE FABRIC

questions concerning heat-treatment, the composition of special alloys, and welding technique. Again, a considerable amount of work has been carried out in many foundries by the British Cast Iron Research Association. The results clearly indicate the Attention might also be given to the recovery of used oil and to its subsequent use. Visits should be paid to oil refiners and to research laboratories dealing with lubrication, and reports should be furnished on the quality of various oils purchased.

RESEARCH DEPARTMENT CHEMICAL LABORATORY

Date *12th May,* 1940

Description of Sample	Contract and Item No. (Where Applicable)	Charge to	Class No.	Rate	Amount
FUEL OIL. Tank No. 165. Contractors Hutcheson & Co., Liverpool.	No. 542 Item 3	Foundry	12		

REPORT

			Specification
Suspended Matter		Nil.	Nil.
Mineral Acid		Nil.	Nil.
Water		Nil.	Nil.
Efflux Time (Redwood), seconds	at 70° F.	818	100 600
	at 100° F.	297	Not above 230
Flash-point (Closed test)		Above 150° F.	Not below 150° F.
Specific Gravity at 60° F.		0·937	Not specified

This sample does not comply with the specification. The viscosity at 70° F. and 100° F. is considerably in excess of the respective maximum limits and, in my opinion, the oil should be rejected.

(Signed) *A. R. Steele*

FIG. 304. REPORT ON SAMPLE OF FUEL OIL

importance of the right quality and consistency of sands for the manufacture of castings. It has been shown that many defects and excessive expenditure of money arise from improper sand-mixtures and control.

Section 3. In any engineering works quantitative spectrographic analysis by means of the microphotometer calls for considerable technique and is amongst the more important types of investigation to be carried out.

Fig. 304 shows a report which might be furnished by the research chemist on a sample of fuel oil which has been received by the firm for its oil-fired furnaces. Another problem is the possibility of a report of skin complaint where the employees' hands are constantly exposed to the actions of grease solvents, and a preventive wash may be introduced for use after work. Other fields for investigation may be methods of fumigation, the finding of

substitutes for proprietary articles, and the destruction of insect pests in canteens.

Section 4. Clothing and uniform equipment, leather and ropes may involve a firm in heavy expenditure. These are some of the items which come within the sphere of the textile technologist, who should make suggestions which, without impairing efficiency, will result in economy.

Application of Research in a Particular Industry

In order to obtain a tangible measure of what can be achieved by systematic research and development work it will be as well to consider a particular industry, and, in view of its wide application, the rubber tyre industry will be of especial interest. It can be said at once that much of the progress in the motor car industry could not have been made had it not been for the rubber industry keeping apace with scientific research and development. If the motor car had merely been the successor to the horse-drawn carriage, a simple modification of the bicycle tyre would have given all the cushioning that the ten-mile-an-hour vehicle demanded in the early days of motor car development, but the motor car was to carry loads of many tons at high speed, was to revolutionize transportation and vitally affect the social life of a large part of the world. A modified bicycle tyre, therefore, was far from being suitable.

It is known that one world-famous tyre firm alone keeps more than 500 engineers employed on chemical research, development, and service work, at a yearly expenditure of more than £200,000. They evolve tyres and other products, and they discover better processes and new uses for chemicals, resulting in many improvements in tyre manufacture which render high service to the users of motor cars and lorries.

An important contribution made to the industry by the development department was the pneumatic tyre for lorries and omnibuses. Previously it was the general idea that, while it was far better for motor cars to be driven on pneumatic tyres, the heavier loads hauled by lorry would always require solid tyres. Research engineers came to the conclusion that even the heavier loads of the lorry could be carried on air. The only problem was to build a sturdy enough pneumatic tyre. The first were greeted with ridicule. Soon, however, the pneumatic-tyred lorry came to be an accepted part of the motor industry, and brought about an entire change in the business of transportation. The next logical step, after hauling goods, was the mass transportation of passengers by motor 'bus, supplementing the transportation by individual cars and bringing a new era into town and inter-town transport.

One development has followed another in tyre making, and the full super-balloon, or what is known as the airwheel, has come in for recognition, being widely used on airplanes. The high-pressure tyres formerly used on airplanes were of the high-wheeled type with relatively small cross-section and operating at 50 lb. to 60 lb.

pressure, while the airwheel operates at $12\frac{1}{2}$ lb. to 20 lb. inflation. The ability of this "all-balloon" tyre to yield sideways and absorb shocks, both vertical and lateral, makes landing and ground manœuvres possible with safety, whereas if duplicated on tyres of the older type, the plane would ground loop or "nose" over.

The passenger car airwheel was a natural outgrowth of the airplane tyre of similar design. The fact that airwheels provided maximum cushioning for airplane landings clearly indicated their advantages for cushioning the modern high-speed, high-performance automobiles. The airwheel absorbs road shocks, protecting the passengers and the mechanism from shocks and making higher speeds possible over bad roads. The prevailing pressure is about 26 lb. for small motor cars and up to 30 lb. for the larger motor cars. Later there came another advance the full airwheel for farm tractors which was the forerunner of the pneumatic tyres now common to tractors and all types of mobile farm implements.

Each tyre size and style is a problem in itself, a problem in chemicals, design and materials, in order to give the maximum quality and wear. Here again the development department has the responsibility of testing the product before it goes out, holding to the principle that it should do its own testing and not compel the public to gamble with untried and experimental tyres.

Many ingenious devices are used in the laboratory for testing tensile strength and specific gravity of fabric rubber and compounds, or measuring tread wear by running test tyres against sandpaper or emery wheels. In addition to all this, constant tests are made on tyres on fleets of motor vehicles so as to note tyre performance under actual conditions before they are put on the market. The most adverse conditions are sought rather than the most favourable ones, and it has only been by constant experiment, testing and surveillance of product reaction that the high quality tyres used on the vehicle of to-day have been evolved.

Patents, Designs and Trade Marks

The average number of patents, designs and trade marks dealt with annually by the Comptroller-General in Great Britain during the last decade has been as shown in Table XXV.

Patents. It is interesting to record that approximately 50 per cent of the total number of patents which are sealed in Great Britain are granted to persons resident in other countries. To cope with all this very important and exacting documentary work a special department is required, headed by the Comptroller-General, which, in spite of its staff of 800, substantially swells the funds of the National Exchequer. The number of patent agents on the official register exceeds 400.

By the Statute of Monopolies, passed in 1623, the Crown is precluded from granting any monopolies except to inventors, as it is considered that inventors should be encouraged to invent for the benefit of the public at large. Patents are obtained by making

TABLE XXV

AVERAGE NUMBER OF PATENTS, DESIGNS AND TRADE MARKS DEALT WITH ANNUALLY IN GREAT BRITAIN

Patents				Designs		Trade Marks			
	Specifications					Applications		Registered	
Applications	Provisional	Complete	Sealed	Applications	Registered	Part A of Register	Part B of Register	Part A of Register	Part B of Register
37,000	23,000	22,000	18,000	21,000	19,000	10,000	300	5,850	300

application to the Comptroller of Patents, General Designs and Trade Marks, and the application can be accompanied either by a provisional specification which sets out the nature of the invention, or by a complete specification in the first instance which not only describes the nature of the invention, but also describes how the invention is to be carried into effect, and contains a claim, or claims, to what is considered to be the novelty of the invention. If a provisional specification be filed with the application, it is the duty of the applicant, if he wishes to obtain the grant of a patent, to file a complete specification within twelve months from the date of his application.

When a complete specification has been filed, the officials in the Patent Office make a search with respect to the novelty claimed, and if the invention be found novel, or after the specification and claims have been amended so as to point out what is old and to claim only what is new, the complete specification is accepted. This acceptance is advertised in the Official Journal published at the Patent Office, and at any time within two months from the date of such advertisement (an extra month can be obtained on payment of a fine before the expiration of the two months), the grant of a patent can be opposed on grounds which are set out in the Patent Act, and if there be no opposition, or after the opposition has been settled in favour of the applicant, a patent can be sealed on the application by payment of a sealing fee.

A patent is granted for a term of sixteen years, subject to the payment of renewal fees before the expiration of the fourth and each subsequent year, extensions of time of one, two or three months being obtainable on payment of the prescribed fees. The sixteen years' period is reckoned from

the date of filing the complete specification. The law governing patents is changed from time to time to meet requirements.

Designs. Design registration is a form of protection accorded to the design of something as it appeals to the eye. This may be the shape or configuration of an article, e.g. the shape of a bottle, or it may be a pattern, e.g. of wallpaper or lace. No protection is obtained by design registration for a mere mechanical construction. A design registration lasts for five years, but can be prolonged for two further periods of five years each, making fifteen years in all. If the novelty of the design lies in some particular part only of the article, it is highly desirable that the application should be made in such a way as to point out that that particular part constitutes the novelty.

Trade Marks. A trade mark may consist of a word or words, or a device, in order to distinguish the goods of the proprietor of the trade mark. There are various restrictions as to what may constitute a "word mark," e.g. it must not consist of a surname, a word having geographical significance, a word having direct reference to the character or quality of the goods, or a deceptive word, nor can it consist of mere initial letters. Inasmuch as the trade marks authorities consider the phonetic rendering of a word, the fancy spelling of a word which would be otherwise unregistrable is not thereby made registrable. In some very special circumstances, however, when a mark which would not otherwise be registrable can be shown to have been used in such a manner as to have achieved distinctiveness in connection with the goods of the proprietor, registration may be permitted. This, however, is usually a difficult and expensive procedure. With regard to "device marks," a notable restriction is that it is not possible to register a "device mark" which consists of a mere representation of the goods, whilst certain crowns, flags, and the use of the word "Royal" are also barred.

A trade mark registration under the Trade Marks Act lasts for seven years, but can be prolonged indefinitely in terms of fourteen years. The Trade Marks Act makes provision for various somewhat technical points in connection with the assignment of rights, and for permitting others to use a registered trade mark on conditions approved by the Registrar.

Technical Reference File

The research department can provide a particularly useful service to all departments by the institution of a section which systematically furnishes brief particulars of all new technical publications relevant to the particular industry, as well as brings to the notice of all concerned reports published by the various institutions and authorities.

CHAPTER XXVI

PURCHASING

Functions of a Purchasing Department

To know markets and to know how and from whom to buy are the primary functions of a purchasing department, and there is always scope for these functions to be intelligently exercised. In many privately-owned firms the owner or partner arranges to do the whole of the more important buying himself. He finds satisfaction in spending his money, and therefore does not desire a purchasing agent to do it for him. Moreover, purchasing brings him into contact with other leaders of industry in a way that cannot be accomplished in any other phase of the business. These contacts, particularly if they have lasted over a period of years, frequently result in the purchasing agent being a mere routine order-placer.

The authority of a purchasing department with respect to finances should always be limited. It should be operated on a form of budget system, whether or not this system has been adopted for the concern as a whole.

Whatever the extent of the powers of a purchasing department, it has certain technical functions to perform. For this reason, it is particularly desirable that the purchasing officer should be a good all-round man, who is both practical and a capable office organizer. To be operated successfully a purchasing department involves careful consideration being given to office routine and office management. At the same time, the successful purchasing agent does not spend the whole of his time in his office, but is careful to be frequently in the factory in order that he may become more familiar with its needs. By this means he is assured of a cordial reception for his purchases by the factory personnel.

The tasks of the purchasing department embrace the issue of specifications but not necessarily their compilation, the letting of orders for material and equipment, the securing of material and equipment when required at the best possible prices and on the best terms of payment, and the maintenance of purchase records that are accurate and complete. The last-named task is by no means the least important because it enables each of the others to be satisfactorily performed.

Purchasing Records

The personnel of the purchasing department is ordinarily divided into two distinct classes, those actually performing the purchasing function and those in charge of the maintenance of purchasing records. In large purchasing departments both these groups become of considerable size, with one or more purchasing agents in charge of the purchase of various types of

commodities, and with a number of clerks in charge of the various record-keeping functions, over whom there is a chief clerk reporting directly to the head of the department.

Sources of Supply

One of the more important types of information which should be on hand, and readily accessible, is a list of manufacturers, approved agents and dealers, who are in a position to supply the articles which are regularly used, or who may be thought to be prospective bidders on any special commodities which may be required from time to time. In order to be of maximum value all such information should be absolutely complete and thoroughly up to date. As far as possible it should be arranged in standard form on a card, and should include the location of the plant and the sales offices, the names of the officers to be dealt with, freight rates, as well as remarks referring to the freight situation between the point of shipment and the factory, and whether the concern is in a position to fill orders from stock, or must manufacture them to order. Other items of interest on these record cards should be facts regarding the manufacturing capacity or usual supplying capacity of the firm, the maximum size of the orders that they can handle, and discounts allowed. All catalogues received should be properly indexed and then filed for easy reference.

Conditions of Contract

Anything which is required other than general stores material should be regarded as a special purchase. The first step in effecting this special purchase should be the preparation and sending out of a "master" inquiry to all who are likely to tender. Whether it be new plant, a machine tool, or some other equipment, it is very desirable that the actual purchase should be made in accordance with clearly defined conditions of contract, furnished by the purchaser. The following conditions of contract will form a basis for any such purchase, and a copy should always accompany each separate order.

CONDITIONS OF CONTRACT

1. *Definitions*

In these conditions the description "Purchaser" shall mean "Messrs. Steele, Stedman & Co." The description "Contractor" shall mean the person or firm whose Tender shall be accepted by the Purchaser.

2. *Tender and Specification*

The Contractor's Tender shall be accompanied by a detailed Specification and general arrangement drawing of the machinery and plant offered. Any acceptance of a Tender shall be in writing and such acceptance is hereinafter called "The Order." The general arrangement and construction shall be in accordance with the best modern practice, all materials shall be of the best quality of their kind and of British manufacture, except where specifically stated in the order, and they shall also comply with the Purchaser's own Specifications enclosed herewith. The Contract shall provide for the supply of machinery and plant suitable and requisite for the duty and operations outlined in the particulars supplied by the Purchaser to the Contractor.

3. *Departure from Specification*

Any modification in the Purchaser's requirements shall be set out by the Contractor in his detailed Specification and the attention of the Purchaser shall be specially directed thereto.

Deviations from the terms of the Contractor's Specification, excepting such deviations as may have been duly agreed in

writing by the Purchaser at the time of placing the order or during the carrying out of the contract, will involve the rejection of the machinery or plant at the option of the Purchaser.

If during the progress of work any alterations or additions are required in respect of which the Contractor intends to make a claim for extras, notice to this effect, together with an estimate of the cost of same, shall be given in writing to the Purchaser, whose written approval shall be obtained before any such alterations are effected.

4. *Subletting*

All items shall be manufactured in the Contractor's own works unless permission has been obtained in writing from the Purchaser to sublet to a firm approved by them. Copies of all sublet orders for material shall be forwarded in duplicate to the Purchaser immediately they are placed. Such sublet orders shall in every case quote the Purchaser's Specification and grade with which the material is to comply and shall also quote full reference to the Tender and the Order, for identification purposes.

5. *Inspection and Testing*

The Purchaser's representative shall have power to inspect the whole of the work whilst in progress, at the Contractor's or Sub-Contractor's works and during erection on site, and reject any material, workmanship, or any part of the plant which he may consider imperfect. The whole of the machinery or plant shall be tested to the satisfaction of the Purchaser's said representative, at the Contractor's and/or Sub-Contractor's work or after delivery and erection as required, at the Contractor's responsibility and expense. Any failure to fulfil the terms of the Specification shall subject the Contractor to rejection of the whole or any part of the machinery or plant at the option of the Purchaser.

6. *Delivery*

The Contractor will be required to pay carriage for all machinery and plant included in the Contract.

7. *Terms of Payment*

The Purchaser's terms of payment shall be 90 per cent on delivery and the balance of 10 per cent when the plant has been tested and put to work to the satisfaction of the Purchaser's appointed Officer, an the Contractor must agree to such terms.

8. *Packing Materials*

No charge will be allowed for packing cases but these will be returned, if desired, subject to the Contractor bearing any carriage and cartage (if any) charges. The packing cases should bear the name of the Contractor and no claim will be admitted for any that are lost or damaged, although all possible care will be exercised in returning such cases when empty.

9. *Erection*

Where machinery and plant is to be erected and set to work by the Contractor he shall provide all scaffolding, tools, lifting tackle and other materials required for the delivery and erection of the machinery or plant, shall carry out the whole of the work at his own risk and expense, and shall complete in every respect ready for service. The Purchaser will not be responsible for loss or damage in respect of any materials or tools belonging to the Contractor which may be brought on to the Purchaser's premises.

10. *Maintenance*

The Contractor shall make good any defect (such not being due to improper use or maltreatment on the part of the Purchaser's servants) in materials and workmanship, or any failure to perform the stipulated requirements satisfactorily, during a period of twelve months after the machinery or plant has been put into service.

11. *Injury to Persons*

The Contractor shall indemnify and protect the Purchaser from any and all damages arising from the performance of the Contract, to which any person may be entitled by reason of or on account of any act or omission of the Contractor, or his employees, during the performance of the work herein mentioned, and for which injury the Purchaser or the Contractor be held liable by law whether the injured person be a servant of any such fellow Contractor or a stranger. All costs and expenses, legal or otherwise, in connection therewith shall be borne by the Contractor. Where plant is being erected on the site a form shall be signed by the Contractor indemnifying the Purchaser against injury to the Contractor's employees.

12. *Insurance against Fire and Accident*

Immediately after the order for installation or purchase of any machinery or plant, the Contractor shall insure the same against fire or accident until it be handed over to the Purchaser after the final testing on the site.

13. *Royalties*

The Contractor shall indemnify, and keep indemnified, the Purchaser from and against all actions, proceedings, claims and demands in respect of any charges for Royalty and/or in respect of any infringement of Patent Rights as applicable to the whole or any part or parts of the machinery or plant ordered by the Purchaser.

Example of Special Purchase

A typical letter accepting a special quotation (i.e. a quotation other than for stores stock material) is given. It should be noted that each feature is carefully defined.

25th July, 1940

Gentlemen,

Gear Wheels and Pinions for
Ten Diesel-Electric Locomotives.

You are hereby accepted to supply in accordance with your quotation of 15th April, Ref. AS/JS, and this Firm's "Conditions of Contract," copy enclosed—

10 *Gear Wheel Rims to Drawing No. AEG*/1931

No. of Teeth	89 (straight teeth)
Diametral Pitch	1·75.
Face Width	6 in.
Tooth Form	To comply with B.S.I. Specification for Traction Gears No. 235.
Material	Molybdenum Chrome Steel, oil hardened and tempered, the teeth to be cut after hardening.
Brinell Hardness	300-400.
Tensile Strength	70 to 80 tons per square inch.
Shrinking Gear Wheel Rim on to Wheel Centre	The rim to be shrunk on to the gear wheel centre, see Drg. No. AEG/1933, which will be supplied by the Purchaser free of charge at your Works, finished machined and ready for the rim to be fitted. The shrinkage allowances to be submitted before the work is carried out.
Price	£55 12s. 6d. each, or a total of £556 5s. (Five hundred and fifty-six pounds, five shillings).

10 *Pinions to Drawing No. EG*/1935.

No. of Teeth	18 (straight teeth).
Diametral Pitch	1·75.
Face Width	6 in.
Tooth Form	To comply with B.S.I. Specification for Traction Gears No. 235.
Material	Medium Carbon Steel, heat-treated and hardened, and teeth to be ground on profile.
Brinell Hardness	450–550 after hardening.
Tensile Strength	Ultimate strength 45 tons per square inch.
Keyway	To be carefully cut to suit the dimensions shown on Drawing EG/1939.

The plug gauge to which the pinions are to be bored will be loaned by the Purchaser.

Price	£8 15s. each or a total of £87 10s. (Eighty-seven pounds, ten shillings).

Grand Total Price for 10 Gear Wheel Rims and 10 Pinions - £643 15s. (Six hundred and forty-three pounds, fifteen shillings).

Note. Tolerance of Teeth as follows—	*Pinion*		*Gear Wheel*
Pitch error, tooth to tooth, max.	0·0025 in.		0·0025 in.
Pitch error, accumulative	0·005 in.		0·010 in.
Tooth thickness, nominal size	− 0·005 in. − 0·015 in.		− 0·005 in. − 0·015 in.
Tooth thickness variation in gear wheels or pinion	0·005 in.		0·005 in.
Backlash between gear wheel and pinion	0·01 in.	to	0·03 in.

The goods to be consigned, carriage paid, addressed to Mr. Lewin, Stores Superintendent.

The gear wheels to be guaranteed for a period of eight years, and the pinions for a period of five years. This guarantee is to cover replacement free of charge in the event of failure during the first twelve months, and if any gear wheel or pinion shall subsequently fail within the guaranteed period it shall be replaced at the above price for a gear wheel or pinion as the case may be, multiplied by the fraction obtained when the life accomplished is divided by the life guaranteed.

Delivery to commence in 12 weeks from this date, at the rate of two gear wheels and two pinions per week.

Please send an acceptance of this order in writing to this office, stating you agree to our terms and conditions.

Kindly arrange for your accounts to be supplied in duplicate, quoting the above reference.

Yours faithfully,
P. Desjardins.

Messrs. Steele, Stedman & Co.,
Huddersfield.

Stores Tenders

Quotations for general stores requirements which cover a period, say, of three, six, or twelve months, should be requested on a standard stores tender form. The following is suggested as a basis -

TENDER FOR THE PURCHASE OF STORES

Note. The Purchaser does not bind himself to accept the lowest or any Tender, and all parties tendering for the supply of Stores must adopt this printed Form, without alterations, additions, or reservations, which Form alone will receive attention. The Prices must be quoted in every respect in the manner prescribed, and must include all charges for Royalty or Patent Rights (if any).

1. *Whole or Portion of Stores*

Tenders are invited for the whole or any portion of the Stores entered hereon.

2. *Deliveries*

Within 21 days after a request shall have been made in writing by the Purchaser or any of their Agents, all Stores shall be addressed and forwarded (unless otherwise directed) to the Purchaser as provided in the Specification and Statement of Quantities shown on the reverse side (see Fig. 305), and shall be sent carriage paid and at the risk of the Contractors.

3. *Quality of Stores*

The quality shall be equal to the Purchaser's sample (if any) and/or be exactly in accordance with the Specification or drawing. In cases where no sample is provided, nor Specification or drawing given, the Stores supplies shall be of an approved make or quality. Nothing herein shall preclude the Purchaser from making trials of similar Stores from other sources.

4. *Empties*

The Contractors shall state on their invoices whether or not empty packages are required to be returned, giving full disposal particulars. Such empties should bear a legible mark or brand showing to whom they belong. No charge will be allowed for empties, but, if required, they will be returned, subject to the Contractor bearing all carriage and cartage (if any) charges. All possible care will be exercised in returning such empties, but no claim will be admitted for any that are lost or damaged.

5. *Invoices and Terms of Payment*

Simultaneously with each dispatch of Stores, a moneyed invoice, in duplicate, having 2½ per cent cash discount deducted and rendered in the Purchaser's name, shall be sent to the Purchaser. Payment will be

Inquiries should quote this reference: STORES/

Specification of Stores Required	(A) Quantity Required	(B) Price per Delivered	(C) Weight per
CONTRACTORS ARE REQUIRED TO FILL IN COLUMNS (B) AND (C)	TOTAL VALUE OF TENDER £		

1. Stores to be forwarded CARRIAGE PAID to
2. DELIVERY to be completed by

CONTRACTORS ARE REQUIRED TO STATE

3. Date delivery will start at the rate of
4. Trade Discount per cent.
5. Source of Origin of Materials
6. Place of Manufacture

$\frac{\text{I}}{\text{We}}$ hereby tender to supply the whole or any portion of the above-mentioned Stores, subject to the foregoing terms and conditions, and to deliver at the time specified.

Signature

Address

Date

This tender must be posted to us to arrive not later than 10 o'clock on the morning of If received after that hour it may not be considered.

FIG. 305. PRO FORMA FOR STORES TENDER

made on the Purchaser's usual pay day in the month following that in which the Stores have been delivered, provided that the Stores are received not later than the 25th of that month.

6. *References*

Contractors who have not previously supplied Stores to the Purchaser shall give reference to other Firms or persons to whom they have supplied similar Stores.

7. *Inferior and/or Defective Material*

The Purchaser shall be at liberty to reject any part or portion of the said Stores, either at the time or respective times of their delivery, or at any subsequent period, if the same be considered by the Purchaser's Agent inferior or defective in quality or otherwise; and upon notice in writing (which notice may be signed by the Purchaser's Agent) of such rejection being given to the Contractor, either by delivering the same personally or leaving it at or sending it by post to the last usual place of business or last known place of abode of the Contractor, the Contractor shall forthwith send for and take, and at the expense of the Contractor in all respects receive the same Stores back from the Purchaser, and if required by the Purchaser supply him with other Stores of such quality as shall be approved by the Purchaser's Agent as aforesaid, in the place and stead of the Stores so rejected. If rejected Stores are not removed by the Contractor within 14 days after receipt of notice of rejection the Purchaser may cause the same to be removed, and charge the Contractor with all expenses incurred in such removal.

8. *Payment*

The Purchaser will pay to the Contractor, at the times and in the manner mentioned in the foregoing Conditions, the sums mentioned and set forth in this Tender in respect of such of the said Stores as may be so required by, and duly delivered to, and approved by the Purchaser.

9. *Failure to Fulfil Contract*

If at any time or times hereafter any part of the said Stores shall not be so delivered to the Purchaser at the place and within the time aforesaid, and in conformity with the Provisions and Specifications aforesaid, or if the Contractors shall become bankrupt or compound with their creditors or shall enter into liquidation (otherwise than in the case of a solvent Company for purposes of reconstruction or amalgamation) then in each and every or any such case, it shall be lawful for the Purchaser or his Agent, if thought fit, forthwith or from time to time to purchase Stores of the same description and quantity (or as near thereto as is practicable) in lieu of the Stores neglected to be supplied or not supplied in conformity herewith, and either then or at any time afterwards during the existence of this Contract, to rescind the same by giving ten days' notice in writing to the Contractors in manner aforesaid. On the expiration of such notice the Purchaser may, if he thinks fit, without further notice to the Contractors, enter into any other Contract or Contracts with any other person or persons whomsoever for the supply of Stores which may be required to complete the remainder of the said Contract, and it shall be lawful for the Purchaser to charge and recover against the Contractors, as liquidated damages, any excess of price over and above the Contract prices herein referred to. For any costs, charges, and expenses which the Purchaser may have paid or become liable to pay, in consequence of any such purchase made by the Purchaser or his Agent, or in consequence of the Purchaser having entered into any such new Contract or Contracts, as aforesaid or otherwise, through the default of the Contractors, the Certificate of the Purchaser's appointed Officer of the amount of such excess of price, and of such costs, charges, and expenses, shall be final and conclusive evidence of the same.

10. *Withholding of Payment*

After making any such purchase, or entering into any such new Contract, it shall be lawful for the Purchaser to hold and retain any money which shall be due to the Contractors on account of this Contract as security for any loss or deficiency, or any excess of price as aforesaid, which the Purchaser may have to pay in consequence of the non-performance and non-fulfilment of the provisions aforesaid, and to apply the same, so far as they will extend in satisfaction of such loss, deficiency or excess, when the amount thereof is ascertained by the Certificate of the Purchaser's appointed Officer.

11. *Evaluation of Stores*

The decision of the Purchaser's appointed Officer with respect to the price or prices, sum or sums of money, which may become

due to the Contractors or to the Purchaser under this Contract, or with respect to the quality of the said Stores, and also in respect of any question that may arise concerning the construction of the provisions aforesaid or the delivery of the said Stores, or any other matter or thing whatsoever referring to the same, shall be final and binding on the Contractors and on the Purchaser.

12. *Indemnification*

The Contractors shall indemnify the Purchaser from and against all actions, proceedings, claims and demands in respect of any charges for Royalty and or in respect of any infringement of any Patent Rights referred to in the note at the head of this Tender.

13. *Customs, Import, and Excise Duties*

All prices submitted on this form of Tender must include all Customs, Import and Excise duties which are in operation on the date when this Tender is forwarded by the Contractor to the Purchaser or which are to operate during the period of the Contract, provided that the provisions of this clause shall not affect the provisions of the Finance Act.

14. *Subletting*

This Contract (or any portion thereof) shall not be assigned or sublet by the Contractors, unless prior permission has been obtained, in writing, from the Purchaser.

Letting Orders

In letting orders, it is essential that the purchasing agent shall know general market levels of prices, as well as the prices which he is being asked for particular materials. The purchasing officer who gives the vendor the most consideration on delivery dates will secure the most favours in the long run. Some purchasing departments have built up reputations of always putting the words "Immediate Delivery Required" on orders. This is either disregarded by the vendor, or it puts the buyer at a complete disadvantage on price. If prices quoted are not adversely affected on that particular order, they are very likely to be so affected on the next one. If the stores stock records are properly maintained, there will usually be no reason for asking vendors to rush most of their orders, and proper delivery dates can be set readily.

It is the practice of some general managers to keep watch over the relations of purchasing agents and vendors, with the idea that the purchasing agent is representing the concern before a large portion of the business world, and that the impression which the trade will get of the concern and its policy will largely be determined by the actions of the purchasing agent. With this in mind, restrictions as to methods of letting contracts are often put on the purchasing department by the management. For instance, requirements as to the securing of competitive bids on large contracts are often imposed on the purchasing department quite as much on account of the impression which this makes on the remainder of the trade as to secure lower prices. Some concerns will not allow the purchasing department to let contracts to any but the lowest bidder without reference to a higher official. A word of caution is however needed here, which perhaps can best be expressed by quoting Benjamin Franklin, who once said, "At a great pennyworth, pause awhile." Those who buy on price only should think this over—if a thing is too cheap, study it carefully before buying. After all, the defects of an article will always be found out by the purchaser!

CHAPTER XXVII

ORDERING SPECIFICATIONS

Importance of Specifications

ONE of the most difficult phases of purchasing department work is the drawing up of adequate ordering or purchasing specifications. These must be governed by the requirements of the design or production department, and yet they must be in accordance with trade practice and trade terms. Specifications are absolutely essential if the product is to be standard, and if a number of quotations are to be asked for and compared. To a very large extent intelligent purchasing depends on drawing up good specifications to which vendors must conform. They are real money-saving investments, as marked economies and improvements can often be made. They frequently prevent a firm having to pay for a proprietary brand or trade mark name, built up at high advertising cost, when the same article can be purchased elsewhere at appreciably less cost. Perhaps even more important still is the fact that specifications enable purchases to be made on a level of quality which is just good enough and not *too* good for the purpose required.

Purchasing by means of specifications is not popular with vendors who have to include in their regular selling price the cost of establishing their trade mark. All concerns, however, no matter how small, will be well advised to use this means of purchase. Care in drawing up the specification and in the inspection of the purchases is the only requirement.

Production and Service Materials

Whether it be production or service material, the materials inspection department will form the link between the design and production departments and the purchasing department.

It should be noted that production material is material entering into the product, and service material is that which is auxiliary to production and does not form part of the product. There will be instances in most works of materials that may be classed in both categories, notably metal bars of one section or another, which may be used equally as well for making components and for making tools or repairing plant. Service material includes articles such as pipes and fittings, which are used in the installation of fixed plant and machinery. It is possible, therefore, for service material to be chargeable to a capital account instead of to one or other of workshop expense accounts. Service materials rarely have the attention which they warrant in regard to specification and standardization, though the same principles apply in their case as in that of production materials.

To give a clear explanation of what constitutes a properly drawn up ordering specification it is suggested that

a number of specifications which are suitable for representative engineering products should be considered. In the first instance consider a purchase specification for round steel bars for automatic machine work. It is suggested that this may be worded as follows—

(*Example* 1.)

Specification for Round Steel Bars for Automatic Machines

1. *Quality*

The Bars shall be of British manufacture throughout, to one of the grades and finishes hereinafter mentioned, and shall be manufactured from steel of the best quality, produced by the Open Hearth (Acid or Basic) Process, and must not show on analysis more than 0·060 per cent of sulphur or of phosphorus. The Manufacturer must supply to our Inspector a full chemical analysis of each cast submitted.

2. *Manufacturing Tolerance*

The Bars shall be manufactured to conform to the tolerances shown in the accompanying Table—

Size of Bar (Diameter)	Bright Finish Tolerance + ·000 −	Blue Finish Tolerance ·000
Up to $\frac{7}{8}$ in. . . .	·003	+ ·010
Over $\frac{7}{8}$ in. and up to $1\frac{1}{4}$ in. .	·004	+ ·015
Over $1\frac{1}{4}$ in. and up to $1\frac{5}{8}$ in.	·004	+ ·020
Over $1\frac{5}{8}$ in. and up to $1\frac{7}{8}$ in.	·004	+ ·025
Over $1\frac{7}{8}$ in. and up to 3 in. .	·005	+ ·050
Over 3 in. and up to 4 in. .	·005	+ ·075
Over 4 in. and up to 5 in. .	·006	+ ·100
Over 5 in. . . .	·007	+ ·150

3. *Finish*

All Bars shall be sound and straight, free from twist, seams and damaged ends, and shall have a workmanlike finish. They shall be uniform in quality, smooth and clean, and come within the stipulated margins of manufacture; they shall be capable of being turned and screwed easily, and shall give a good machined finish. They shall be supplied in one of the following finishes, as stipulated on the order—

(*a*) Bright . .	{ Cold rolled Drawn Turned Ground
(*b*) Blue . .	Reeled

4. *Tests*

(*a*) Tests will be taken at the rate of one tensile test and one bend test from every 50 bars or part thereof, from each size in each cast as submitted for inspection.

(*b*) The test pieces selected must be prepared to the required form without any reheating or other manipulation whatever.

(*c*) Tensile Test Piece.—This test shall be carried out on a test piece having a gauge length equal to four times the square root of the area. In the case of bars $1\frac{1}{2}$ in. and over in diameter, the longitudinal axis of the test piece shall be $\frac{7}{16}$ in. from the surface of the bar.

(*d*) Bend Test Piece.—Bars up to and including 1 in. in diameter shall be tested full size.

(*e*) Bars over 1 in. in diameter shall be turned down to a diameter of 1 in.

(*f*) The tensile test pieces must withstand the tests indicated below—

Maximum Stress	Minimum Elongation	
	Cold Rolled and Drawn	Other Finishes
Tons per sq. in.	Per cent	Per cent
35 to 42	15	20
28 to 35	17	24

(*g*) The bend test piece must withstand being doubled over until the internal radius is equal to the diameter of the test piece, and the sides are parallel, without fracture, and without developing any open cracks on their outer surfaces.

(*h*) A copy of the results of all tests, which must be made in the presence of our Inspector, signed by the Contractor, or his Representative, is to be supplied to our Inspector.

(*j*) A portion of any tested bar to be supplied to us when requested, free of cost, for testing at our Works.

5. *Marking*

(*a*) The Manufacturer shall adopt a system *of marking the material in all the stages of* manufacture with its cast number and fur*nace letter, and our* Representative shall be *given every facility for tracing the same to its source, if desired.*

(*b*) Each bar 1 in. in diameter and upwards shall be clearly stamped, within 6 in. from one end, with the Manufacturer's name and cast number. All bars under 1 in. in diameter shall be fastened together in bundles; each bundle must have a metal label attached giving this information.

6. *General Clauses*

(*a*) The material shall be manufactured in the Contractor's own Works unless permission has been obtained to sublet the whole of the order or any portion thereof to an approved firm, in which case a copy of the sublet order must be forwarded to our address, as above, immediately it is placed. When the steel is not of the Contractor's own make, he shall furnish to us, in writing, the name of the Manufacturer and his cast number.

(*b*) Suitable test pieces to be provided when required by us for further tests without charge.

(*c*) Material will not be accepted which does not withstand the specified tests, or in which the tests reveal any defect, and any material found to be defective after delivery will be returned to the Contractor at his own expense, notwithstanding that it may have passed the tests required by this Specification, and have been accepted by our Inspector.

(*d*) Our Representative shall have free access to the Works of the Manufacturer at all reasonable times, shall be at liberty to inspect the manufacture at any stage, and to reject any material that does not conform to the terms of this Specification.

(*e*) The Manufacturer shall furnish the material for any tests required, and shall also provide the necessary labour and appliances for carrying out such tests free of charge. Failing facilities at his own Works, the testing shall be carried out at a testing works approved by us at the expense of the Manufacturer.

(*f*) Due notice shall be given to us when the material is ready for inspection.

(*g*) Material must not leave the Maker's works before a forwarding certificate has been obtained from our Inspector, and this certificate must be forwarded to us, attached to the invoice, as evidence that the material *has been duly accepted.*

Particular attention should be paid to what have been described, in the foregoing, as "General Clauses." They are very important. Broadly speaking, they should be included in all purchase specifications, only those modifications being effected which the nature of the purchase makes necessary. In the four further equally representative examples it will be readily appreciated that the general clauses should be inserted in each case; they are merely omitted now to avoid repetition.

(*Example* 2.)

Specification for Brass Rods

1. *Quality*

The Rods shall conform to the following analysis—

Copper . .	Not less than 57 per cent and not more than 60 per cent.
Zinc . .	Not less than 38 per cent and not more than 40 per cent.
Lead . .	Not less than 1·0 per cent and not more than 2·0 per cent.
Tin (if present)	Not to exceed 0·5 per cent.

The total of other impurities must not exceed 0·75 per cent. The Manufacturer shall, at his own expense, supply an analysis when required to do so.

2. *Finish*

The Rods shall be sawn off square at the ends to a length of 10 ft. unless otherwise specified on the order. They shall be sound, straight, free from twists and all other defects, capable of being turned and screwed easily in automatic machines, and shall give a good finish. The Manufacturer's name shall be stamped on each Rod not more than 6 in. from the end.

3. *Manufacturing Tolerance*

The Rods shall be manufactured within the following limits—

	Tolerance
Round Bars under $\frac{3}{8}$ in. dia.	+ 0·000–0·002 in.
Round bars $\frac{3}{8}$ in. dia. and under $1\frac{1}{2}$ in. dia. . .	+ 0·000–0·003 in.

Round Bars $1\frac{1}{2}$ in. dia. and over	+ 0·000–0·004 in.
Hex. and Square Bars under $\frac{5}{8}$ in.	+ 0·000–0·003 in.
Hex. and Square Bars $\frac{5}{8}$ in. and under $1\frac{5}{8}$ in.	+ 0·000–0·004 in.
Hex. and Square Bars $1\frac{5}{8}$ in. and over	+ 0·000–0·005 in.

4. *Tests*

One bar will be selected from every complete fifty bars, or part thereof, for testing; one tensile test, one cold bend test, and one hot bend test will be taken from this bar. The test samples shall be removed from the bar by nicking and breaking, and the fractures thus revealed must show no sign of piping or any other defect.

The prepared test pieces shall comply with the following tests :-

Tensile Test. The tensile strength of bars under $\frac{1}{2}$ in. diameter or across the flats shall be not less than 28 tons per square inch with an elongation of not less than 22 per cent, and in the case of bars $\frac{1}{2}$ in. and over in diameter or across the flats shall be not less than 25 tons per square inch, with an elongation of not less than 22 per cent. In each case a test bar having a gauge length which equals $4\sqrt{\text{area}}$ shall be used.

Bending Test. Test pieces cut from bars up to 1 in. diameter or across flats will be bent as rolled. In the case of bars in excess of these sizes, test pieces shall be machined eccentrically to 1 in. diameter so that the test piece includes the skin at one side. The above test pieces must withstand bending cold round a bar 3 in. diameter through an angle of 90° with the outside skin in tension and also bent at a red heat through an angle of 180° and flattened close up. In each case the bends must show no sign of fracture or failure.

5. *Subletting*

The Rods shall be rolled or extruded in the Contractor's own works unless permission has been obtained to sublet the whole of the order or any portion thereof to an approved firm, in which case a copy of the sublet order must be forwarded to us immediately it is placed.

6. *Results of Tests*

A copy of the results of all tests, which must be made in the presence of our Inspector and signed by the Contractor or his Representative, to be supplied to the Inspector.

7. *Additional Tests*

A portion of any tested Rod to be supplied to us when requested, free of cost, for testing at our Works.

(*Example* 3.)

Specification for General Steel Castings

1. *Quality*

The Castings shall be of British manufacture throughout and produced by an approved process and must not show on analysis more than 0·060 per cent of sulphur or of phosphorus. The Manufacturer shall supply the analysis of each cast when required to do so.

2. *Grade*

The steel shall be of one of the grades enumerated in Clause 8 as will be stipulated on the order

3. *Annealing*

All Castings shall be thoroughly annealed by heating to a temperature not less than the normalizing temperature and allowing to cool slowly from the maximum temperature in a practically uniform manner.

4. *Accuracy*

The Castings shall be accurately moulded in accordance with the pattern or the working drawing supplied by us, and the initials of the Manufacturer and date of manufacture shall be cast on each article when practicable, otherwise these particulars, together with the actual cast number, must be stamped thereon, close to the moulded number of the pattern.

5. *Discrepancies*

The Manufacturer shall compare the pattern with the drawing sent, in order to be satisfied that they are in agreement. If any discrepancy is found it must be pointed out to us before proceeding with the work.

6. *Rectification*

No welding or filling of any description shall be undertaken without the consent of our Inspector and any defects, from whatever cause, shall be submitted to our Inspector for sanction before welding. No dressing of salammoniac or other solutions must be applied to the castings until these have been passed by the Inspector.

7. *Test Blocks*

One additional Casting, for testing to destruction, to be supplied with every fifty or lesser number ordered, this Casting to be selected from the bulk by our Inspector, and tested in any way considered desirable by him. All Castings weighing 1 cwt. or more must have test blocks formed on and cast simultaneously with each Casting, of such size and in such position in the mould as will furnish test pieces which shall be representative of the remainder of the metal. In the case of Castings weighing less than 1 cwt., 10 per cent of the Castings in each cast submitted shall be cast with such test blocks as indicated above.

8. *Tensile Test*

From the test blocks referred to in Clause 7 above our Inspector will make a selection at the rate of one for each cast or one from each Casting weighing over 1 cwt., from which the test pieces must be machined cold without any reheating whatever. The tensile test piece shall be machined to a diameter of 0·798 in. with a gauge length of 3 in., or if this is impracticable of 0·564 in. with a gauge length of 2 in. This test piece must comply with the requirements for the respective grade indicated in the table below—

Grade	Tensile Breaking Strength	Minimum Elongation
	Tons per sq. in.	Per cent
1	26 34	20
2	35 40	*15/10
	Over 40	10

* The figures representing the tensile strength and elongation must total to not less than 50.

9. *Bend Test*

This will be taken from Grade 1 Castings only, and the test piece shall be turned to 1 in. diameter, 9 in. long and must withstand being bent cold through an angle of 120° round a bar 2½ in. diameter, without showing any signs of fracture.

10. *Machining of Test Pieces*

All test pieces shall be machined cold without reheating or any other manipulation whatever.

11. *Additional Tests*

A portion of any tested Casting to be supplied to us when requested, free of cost, for testing at our Works.

12. *Markings*

The Manufacturer shall adopt a system of marking the material in all the stages of manufacture with its cast number and furnace letter, and our Representative shall be given every facility for tracing the same to its source if desired.

(*Example* 4.)

Specification for Steel Files

1. *Quality*

The Files must be of the best quality and must have the Manufacturer's name and this Firm's initial legibly stamped, when hot, on the tang.

2. *Tests*

The quality of the Files will be ascertained by means of tests carried out in the following manner

Two sides of every File tested must together cut from a steel bar (of the chemical composition and hardness defined in Clause 4) in not more than 30,000 strokes, lengths in accordance with the following table—

Teeth per inch	Amount to be Removed from Bar when each stroke is 6 in.	Teeth per inch	Amount to be Removed from Bar when each stroke is 6 in.
	inches		inches
16	4·5	23	3·1
17	4·2	24	3·0
18	4·0	25	2·9
19	3·8	26	2·8
20	3·6	27	2·7
21	3·4	28	2·6
22	3·3	29	2·5

In the case of round Files, the amount to be removed will be that shown in the Table for a File having one tooth per inch above the actual number.

When practicable each File will be tested with a stroke of 6 in. on a bar 1 in. square with a pressure of 30 lb. In cases where the stroke is less than 6 in., the amount of metal to be removed from the bar will be varied in direct proportion to the stroke from the

figures in the above Table. When the test bar is other than 1 in. square, the pressure will be maintained at 30 lb. per square inch of the cross-sectional area of the bar. The cutting strokes will be made at the rate of 50–55 per minute.

3. *Selection of Samples*

Samples for testing will be selected by our Inspector at the Manufacturer's Works, at the rate of two Files from each size of every batch submitted for inspection, and in cases where 6 gross or more of any one size are submitted, the consignment is to be split into batches of not more than 6 gross each, and two Files will be selected therefrom. Each batch will be sealed by our Inspector and the seals must remain unbroken on delivery at our Works. The tests will be carried out at our own Works.

4. *Hardness of Test Bars*

The Steel Bars used in the above tests will have an analysis approximately as follows -

Carbon	Silicon	Manganese	Sulphur	Phosphorus
per cent	per cent	per cent	per cent	per cent
0·60	0·30	0·80	0·035	0·035

Each Bar will also be tested for hardness before use, and none will be utilized having a Brinell hardness number of more than 218 or less than 218 when tested with a ball having a diameter of 10 millimetres and a pressure of 5000 kilogrammes, or a Ludwig hardness number of from 217 to 191 when tested with a 90° cone.

(*Example* 5.)

Specification for Steel Conduit and Fittings for Electrical Wiring

1. *Quality*

The Conduit shall consist of heavy gauge Welded or Solid Drawn Steel Tubing in straight lengths not exceeding 15 ft. long, rodded and screwed and reamered at both ends, and, except as otherwise stated in this Specification, the Conduit and Fittings shall conform to B.S.I. Specification No. 31– 1933, Class "B."

2. *Finish*

The Conduit and all Fittings shall be either stove enamelled or hot galvanized as specified on the order, the Conduit to be enamelled or galvanized both inside and out.

3. *Inspection*

The Conduit and Fittings will be inspected by our Inspector at the Manufacturer's Works before delivery; 5 per cent of the Conduits submitted shall be selected for testing, and portions will be cut from these for bending and flattening tests; in the case of Galvanized Conduit and Fittings a galvanizing test will also be made.

4. *Mechanical Tests*

(*a*) *Bending Test.* The bending test shall be made on a suitable appliance, and the portions selected shall be capable of being bent to an internal radius of two and a half times the diameter of the Conduit through an angle of 180° without showing any signs of fracture or failure at the weld.

(*b*) *Flattening Test.* A portion of Conduit 6 in. long must withstand being flattened until the internal walls of the Conduit meet, and subsequently being bent over on itself until the inside surfaces meet, without showing any signs of cracking or material defects.

(*c*) *Galvanizing Test.* The quality of the galvanizing shall be tested by plunging samples of the Galvanized Conduit or Fittings in a freshly made neutral solution of sulphate of copper and allowing to remain in the solution for one minute, when they shall be withdrawn and wiped clean. The galvanized samples shall admit of this process being performed four times without showing any signs of a deposit of metallic copper on the samples.

(*d*) *Test for Malleability of Cast-iron Fittings.* Articles selected at random from each batch shall be capable of being deformed in configuration by hammer blows without showing any signs of fracture.

Modification of Specifications

At times specifications may be modified to suit the needs of the vendor. Thus slight and unimportant modifications of specifications may bring considerable reductions in the quoted price, because the revised specifications will fall within the standard product of one or more of the vendors. Sometimes specifications are not determined by the buyer or by the vendor,

but by the state of the market. This is particularly true with those commodities which are subject to wide quotation. The purchasing department can then only determine the grade to be bought, and see that the commodity comes within the market regulations for the grade ordered.

CHAPTER XXVIII

INSPECTION STANDARDS

In most engineering factories there are three main divisions of inspection and testing. The order in which these occur is as follows –

(1) Inspection and testing of materials and component parts supplied from outside sources in accordance with standard ordering specifications.

(2) Inspection of partly finished and finished components during manufacture, as well as final inspection of the product after assembly in accordance with stipulated requirements, embracing size and finish.

(3) Testing for performance of the completed product in accordance with a predetermined standard, which is usually laid down in the functional design.

Materials Inspection

Inspection is a necessary safeguard, as much against honest mistakes and errors of judgment as against fraud. A firm buys material for the most part to sell again in a different form, and their own reputation is endangered if they are careless about the quality of the material purchased. It should be a condition of a purchase order that while the purchase is made subject to inspection by the buyer, this does not relieve the supplier of his responsibility. (See "General Clauses," Chapter XXVII, page 392.)

When it is necessary to inspect contracts at the supplier's works, still greater distinction and responsibility is involved on the part of the visiting inspectors. In particular, the inspector should be able, as the result of his visits, to report on the capacity and reliability of the suppliers, e.g. whether their organization and management are such that they will ensure uniformly reliable products, etc.

It was shown in the previous chapter that in a large measure inspection standards relating to materials should be embodied in ordering specifications, the tests which are specified generally being carried out as a matter of routine before material is accepted. Not all purchases will justify the making of definite material tests, and dependence is, very properly, placed largely on the undertaking of the contractors to provide material complying with the specification furnished to them, or in some cases furnished by them. The latter alternative is very important, because it is the first business of a materials inspection department, in drawing up ordering specifications, to pay regard to what is already on the market. This department should be responsible for the quality of the various materials dealt with, whilst the responsibility with regard to the actual size and finish should be dealt with by the works' personnel. Accordingly, if material is received in an unsatisfactory state the matter should

be taken up with the manufacturer through the materials inspection department and, if necessary, the material returned to the manufacturer at his expense.

The following proposals are submitted as a guide for the efficient and economical running of a materials inspection bureau–

(1) Steel bars, blooms, sections, plates, general steel castings, and malleable iron castings should be tested only, but not surface inspected or gauged, at the manufacturers' works.

(2) General steel plates, steel ferrules, taper and split pins, iron rivets, tubes and fittings for gas, water, etc., common bolts and nuts, and general quality rivets should all be purchased without inspection, at the manufacturers' works.

(3) Special quality rivets and bolts should be inspected at the manufacturers' works.

(4) Steel tubes, copper tubes, copper pipes, copper rods and brass rods should be tested, and a small proportion examined for size, finish, etc., at the manufacturers' works.

MATERIALS INSPECTION BUREAU

CERTIFICATE OF INSPECTION OF MATERIALS

This Certificate must accompany, and, with the Material passed hereby, agree with the Invoice

Certificate No.

B 4522

I.B. Ref

Messrs.

Order

Issued from

Quantity Passed	Full Description of Material	Quantity Rejected

Remarks

Signed

Date

FIG. 306. CERTIFICATE OF INSPECTION

(5) Files, aluminium ingots, and manganese copper ingots should be tested or analysed after delivery.

Inspection Certificate

A visiting inspector should carry with him the private stamp of his firm, and he should, wherever practicable, imprint this on everything he accepts. After doing so he should issue a certificate of inspection in accordance with the sample given in Fig. 306.

Universal Testing Machine

The machine illustrated in Fig. 307 permits of one operator carrying out any of the usual mechanical tests tension, compression, transverse, bending, and shearing. It comprises a pumping unit, straining unit and load indicating unit, and gives visible indication of the load on both sides of the machine, on a graduated dial of large diameter. A loose pointer indicates the maximum load. Two sets of graduations can be provided on the dial for high and low capacities. A lever control is embodied to alter the capacity when the machine is arranged for two capacities. The height is convenient for the operator to position specimens. The front columns are graduated to provide a means of measuring the deformation of specimens. Visible "tell-tale" signal lamps on the control panel indicate the operation of the maximum pointer circuit and relay switch when such is arranged for automatic load maintenance tests. Loads can be automatically maintained for any period.

Oil is used as the pressure medium, and this is delivered to the cylinders of the straining unit via a control valve. The pressure oil operating upon the rams forces the intermediate crosshead upwards, which action is utilized to carry out tensile tests between the moving and the lower (fixed) crossheads. Compression and shearing tests are made between the upper surface of the moving crosshead, and the under side of the top fixed crosshead. For transverse tests the two dogs on the moving crosshead are used to support the specimen, which is forced against a pressure foot secured to the top crosshead.

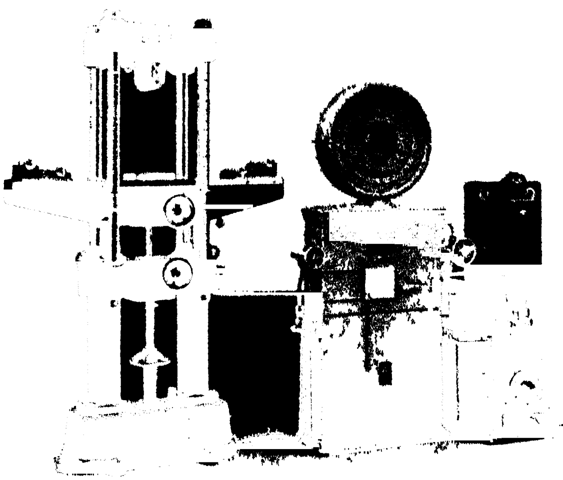


Fig. 307 Universal Testing Machine

The resistance of the specimen determines the pressure within the

straining cylinders, which are in communication with a smaller cylinder situated in the load indicator cabinet. The ram of the small cylinder, which is in direct connection with the weighing mechanism, is reduced in area (by a definite ratio) to that of the rams of the main straining cylinders, so that weighing and straining are effected through the medium of hydraulic pressure.

Machines of this type can be obtained in many capacities, the particulars which follow being representative of good practice for 10-ton and 100-ton capacity machines respectively—

Capacity	10 tons	100 tons
Smallest Graduation . . .	0·02 ton	0·25 ton
Alternative Graduations in Centals	20,000 lb.	200,000 lb.
Smallest Graduation . . .	50 lb.	500 lb.
TENSION TEST		
Distance available between Holders . . .	3 in. to 21 in. Flats: 0 in.–$\frac{1}{4}$ in.	$3\frac{1}{2}$ in. to 24 in. Rounds: $\frac{3}{4}$ in.–1 in.
Extension Scale .	Marked 0–18 in. by $\frac{1}{10}$ in. and $\frac{1}{16}$ in.	Marked 0–20 in. by $\frac{1}{10}$ in. and $\frac{1}{16}$ in.
Maximum Size of Specimen that Machine will accommodate .	Rounds: 1 in. dia. Flats: 2 in. wide × $\frac{1}{2}$ in. thick	Rounds: $1\frac{3}{4}$ in. dia. Flats: 4 in. wide × $1\frac{1}{2}$ in. thick
COMPRESSION TEST		
Space available between Platens	20 in.	21 in.
TRANSVERSE TEST		
Maximum Span . .	45 in.	51 in. (Maximum load 50 tons)
Maximum Height of Test Piece .	12 in.	12 in.
Width between Columns .	$6\frac{7}{8}$ in.	$10\frac{1}{2}$ in.
Maximum Deflection possible .	4 in.	5 in.
BEND TEST		
Minimum Span . . .	6 in.	6 in.
Stroke of Rams . . .	18 in.	$20\frac{1}{2}$ in.

Impact Test

Whilst tensile, compression and hardness testing machines are extremely valuable for ascertaining the dead load resistance of a material, they do not necessarily indicate its resistance to shock. This important characteristic of a material is obtained only by the "Izod" impact test which is universally adopted, and which consists of the application of a single blow to a specimen of prescribed form and held as a cantilever.

The specimen is notched at its striking face to ensure that the effect of the blow is definitely located at a fixed distance from the point of impact. The blow itself is imparted to the specimen by a pendulum of prescribed weight falling through a height sufficient to exercise the maximum capacity of the machine. In addition to indicating the toughness of a material or its power to resist shock, the Izod test is useful to the manufacturer by virtue of the fact that it is able to reveal incorrect chemical composition; for example, a material containing too high a percentage of sulphur or phosphorus will tend to be brittle and therefore have a

low impact value. Other defects in the chemical composition of a material are also indicated by the Izod test. A material which has been cold worked but has not been normalized will fall short of its maximum Izod impact value according to the amount of cold working to which the material has been subjected. The impact value of a specimen will indicate whether a material has been correctly heat-treated.

The variety of material required to resist shock is ever increasing, and the Izod test is now applied to all grades of iron and steel, iron castings, steel sections, material used in the manufacture of nuts and bolts, non-ferrous material, insulating material, porcelain, timber, glass, fire brick, etc.

Impact Testing Machine

The impact testing machine illustrated in Fig. 308 consists of a base casting upon which are erected two rigid "A" frames of improved design. Between the apex of these frames is swung a pendulum, mounted in ball bearings in such a way that all lateral movement is prevented. A vice provided with suitable grips for holding the specimen is secured to the base casting. The pendulum is fitted with a plug into which a hardened steel insert is dovetailed and which strikes the specimen at a fixed distance above the surface of the gripping dies. This insert is renewable without removing the plug from the pendulum. A graduated quadrant is secured to the "A" frames and the impact value of the specimen is indicated upon this quadrant by means of a loose pointer carried forward by the pendulum.

To make a test the specimen is positioned first in the vice. The pendulum, raised to its maximum position, is then released by means of a trigger, and on its downward swing breaks the specimen. The residual energy in the pendulum causes it to continue its arc, and the extent of its travel (which is also a measure of the residual energy)

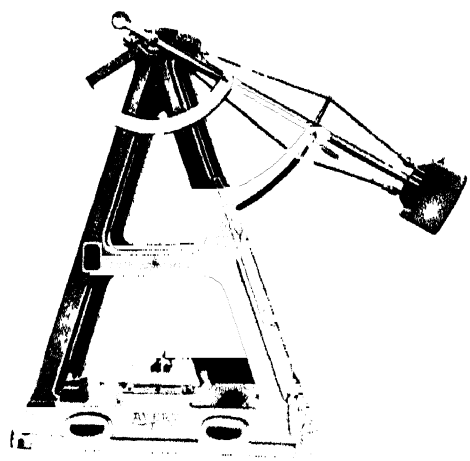


FIG. 308 IMPACT TESTING MACHINE

is indicated on the quadrant by means of the loose pointer. While the specimen is being removed, the pendulum may be rested against the stop on the frames. This stop falls away when the pendulum is raised. After fracture, the specimen should be examined, as certain qualities of a material may be judged from the appearance of the fracture.

An inverted quadrant, by which the reading of the test results is facilitated, is graduated at each side of the vertical line from zero up to the maximum capacity of the machine. The impact value of the specimen under test is indicated on the right-hand

side of the quadrant, while the left-hand side is graduated to enable the pendulum to be adjusted to various capacities; it will be realized that if the height of fall of the pendulum is altered the striking velocity is also altered.

The standard graduation for the quadrant is 120 ft.-lb. It can be graduated in the metric standard to 17 kilog.-metres, or in both English and metric standards, in which case the metric graduations will be from zero to 16·6 kilog.-metres. The graduations on the quadrant are fixed by the vertical fall of the pendulum, the position of the pendulum at the various heights being measured by standard gauges.

The British standard notched bar test piece (B.S.I. Spec. 131) is 10 mm. × 10 mm. in cross section, the form and depth of the notch being illustrated in Fig. 309. The specimen is positioned in the vice by means of a positioning gauge, thus ensuring that the blow shall be struck at the requisite height above the notch (22 mm. for 120 ft.-lb. machine).

It is recommended that at least three tests are made of a material and the average result taken. For this purpose specimens are often prepared in lengths having three notches, which are so arranged that the second test can be carried out in an opposite direction to the first and last tests.

The type of form recommended for use in connection with orthodox material tests is shown in Fig. 310.

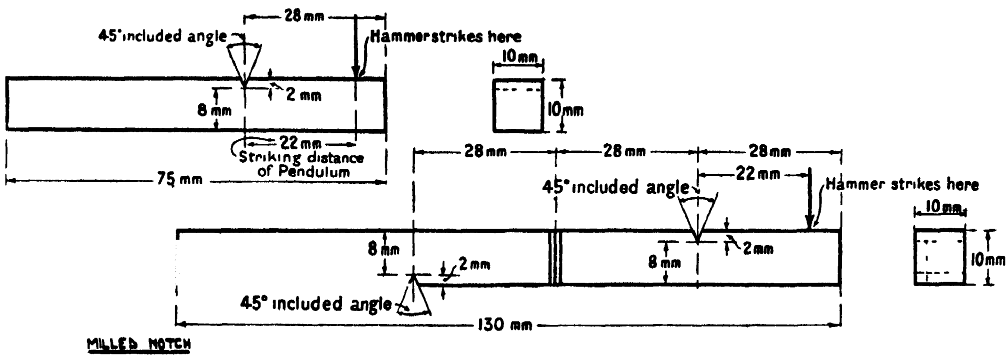


FIG. 309 BRITISH STANDARD NOTCHED BAR TEST PIECE

Limits

After materials inspection, workmanship has to be controlled in regard to dimensions and finish. The working drawing should specify both dimensions and finish - the former in precise measurements of high and low limits for dimensions that are important for interchangeability or performance, and the latter by description to be interpreted by inspection practice and sometimes supported by samples approved by the customer. Usually the more difficult inspection standards to fix are those relating to performance, and the use of a questionnaire may be the best way to build up the requisite standard.

It is the accepted drawing office practice, when a nominal accuracy is

REPORT OF TESTS UPON

Sheet No. ....

Tested by.. . ...

Report Date ....

Date of Test	Test No.	Cast No.	Description of Materials	Maker	Length of Specimen	SECTION	YIELD POINT ELASTIC LIMIT	STRESS	STRAIN	FRACTURE		REMARKS
						Area in square inches	Tons per square inch	Tons per square inch	Elongation per cent	Contraction of Area per cent	Appearance	

SPECIFICATION

Cast No.	CHEMIST'S ANALYSIS					BRINELL HARDNESS		BEND TEST				
	C.	Si.	Mn.	S.	P.	Test No.	Number	Dimensions—Inches	Test No.	Cold	Hot or Temper	

SPECIFICATION

Remarks

Signature

FIG. 310. REPORT OF MATERIAL TESTS

not enough, to include the limits of dimensions on working drawings of components. Sometimes there is a tendency to adopt needlessly fine tolerances, and it is a matter of great importance to ascertain the real requirements demanded by economy in assembly and efficiency in performance. This exploration might reasonably be a function of the research and development department, and be associated with after-sales service experience, and investigation of customers' complaints.

Finished Work Inspection

With finished work inspection within the factory it is highly important that the exact nature of the inspection required for every measurable state of inspection of an article should be clearly and fully laid down in writing. Any other arrangement can only be regarded as unsatisfactory. In other words a specification should be drawn up to cover the inspection required. Unless this is done it is not unlikely that too much attention will be given to certain details, or certain features of these details, and not enough to others. Optical instruments and X-ray apparatus are indispensable with certain types of high-class inspection work. In some instances a diagram which has been specially prepared for finished work inspection will prove advantageous.

If again we refer to the manufacture of tyres, as in the example chosen in Chapter XXV, inspection should begin with the raw materials. The fabric should be passed over a glass-top table, brilliantly lighted from beneath, to reveal any imperfections. The compounds should be checked by the laboratory staff and the rubber should be inspected by expert technologists. The inspectors should be in evidence through every step of the production process, in the wash room, in the driers, and especially in the mill room, to see that specifications as to time and temperature of milling are rigidly adhered to, also in the compound room to see that quantities and weights are exact. They should be especially exacting in the calendar room where inspection of gauge and heat is continuous. An inspector should pass every tyre before and after the putting on of the tread, he should be in the pit to see that pressures are kept up and that there is no over-cure or under-cure, and he should take a last look at the tyre in a final inspection where every detail is passed on.

Avoidance of Undue Elaboration

It will be found that the most carefully worked out system of inspection standards will not entirely prevent defects of quality in the product. A well-balanced judgment is therefore necessary to avoid undue elaboration and stringency in inspection, which is not only costly but is liable to defeat its own object.

Without exception finished work inspectors should be answerable directly to the management—never should they be under the jurisdiction of the shop supervisory staff.

CHAPTER XXIX

STOREKEEPING

The Stores Superintendent

It is important that the officer in charge of the stores department should be a sound practical man with technical experience, otherwise it is inevitable that the department will perpetually suffer a severe handicap, mistakes being prevalent and the works personnel losing confidence in the misguided efforts of their confrères in the stores department. The stores superintendent's principal duties may be summarized as follows --

(1) He must see that the total stock maintained involves the least capital expenditure consistent with requirements.

(2) He must work in conjunction with the central planning office and place orders on the works for economic manufacturing quantities.

(3) He must fix maximum and minimum stocks for each item and review these systematically to meet changed conditions.

(4) He must constantly review the position regarding the possibility of "dead" stocks, and when such arise should defer selling at a greatly reduced price until completely satisfied that the works are unable to use the material economically in some new field.

(5) He must take what steps are necessary to ensure that the stores catalogues and stock lists used in the works are kept up to date.

(6) He must ensure that the entire stores service is efficiently controlled and that its working expenses are kept at the absolute minimum.

Maximum and Minimum Stocks

For economic working the quantity of stock held should be determined by the rate at which stock is used up and the rate at which the stock can be manufactured. For any particular article the cost is composed of the actual manufacturing cost and the cost of keeping it in the stores, i.e. when an article is kept in the stores it represents capital lying idle and interest is chargeable on this capital whilst the article is in stock. By balancing the quantity made in a batch with the time kept in the stores, a quantity giving minimum cost can be found. This quantity is the size of a batch which places the total cost of manufacture and storage at a minimum. The minimum quantity held in the stores is determined by this optimum batch size. The minimum quantity must be sufficient to supply production with finished parts during the time in which a single optimum batch is made. For example, assuming that 100 details are required per week and the optimum batch size is 350 taking one and a half weeks to make, then the minimum stock should be 150. This number will supply production during the time a batch of

350 is being made. Details need not be ordered in single batches. Two, three, or more independently economic batches may be ordered, depending on the minimum stock. The maximum stock to be carried for any item, whether it be manufactured or purchased, will be dependent on various conditions, but more usually will be based on a 1, 2, 3, or 6 months' user.

The procedure for replenishment of stocks, whether raw materials, part finished, or finished articles, will originate with a stores issuer who should keep bin cards on which are marked the agreed minimum and maximum quantities for the material or articles concerned. As parts are booked in or out appropriate entries should be made on the cards. When the stock reaches the minimum quantity the stores issuer should inform the stores order office. The type of stores stock card recommended is shown in Fig. 311. It is suitable for articles whether manufactured within the works or whether purchased from an outside source.

______ Stores ______ Stock Order Card ______

Standard Catalogue No ______ Material ______

Year	Building	Maintenance

Maximum Stock ______

Minimum Stock ______ Standard Weight ______ Inspection ______ Contract ______ Item ______

Date	Stock		Quantity to be Ordered	Required for and delivery date	Approved	Ordered		Firm or Works	Serial Order No.	Supplied		Serial Order No.	Supplied	
	Building	Maintenance				Date	Quantity			Date	Quantity		Date	Quantity

FIG. 311. STORES ORDERING CARD

Layout of Stores Buildings

Some of the more important details concerning the initial layout of stores buildings should be noted.

Necessity for Adequate Covering. It is a short-sighted policy to leave perishable material exposed to the weather. In all cases provision should be made for such material to be placed under cover of a substantial character. Duplicate racks should be provided, one for incoming stock and one for stock being drawn upon. This arrangement overcomes the difficulty of apparent "dead" stock, which is liable to corrode after a time, and it allows the minimum of handling.

Lighting. Advantage should be taken of all natural light by arranging the stacks so that the light shines down the gangways (Fig. 312). Provision should also be made for suitable artificial lighting.

Gangways. Main gangways that will permit of unhampered one-way traffic should be provided (Fig. 313). It is essential that the width of the

gangway should be sufficient to allow easy handling of stocks, the minimum width being 2 ft. 6 in. Long or bulky articles may prove quite unmanageable in narrow aisles.

Receiving and Dispatching Centres. There should never be any question of a depot at a main stores being used

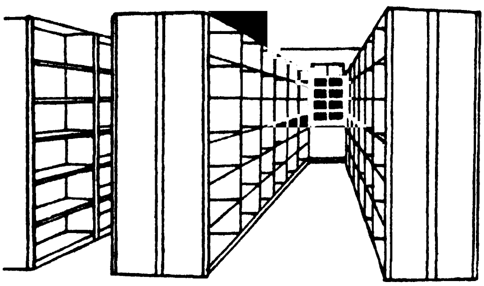


FIG. 312. ARRANGEMENT OF STORES STACKS TO SUIT NATURAL LIGHTING

both for receiving and dispatching. It is altogether too confusing. Adequate provision should be made for ingoing and outgoing stocks. For many items simple openings can be formed to take hatches or windows.

Enclosures. Considerable economy can be effected by using stacks of shelving instead of partitions. High stacks can be made to form an enclosure or partition by sheeting in the backs. Where the light is poor, expanded metal or similar panels can be used.

Loads. Careful consideration should be given to the nature of the goods

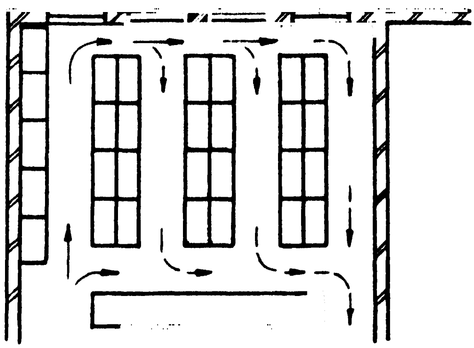


FIG. 313. ARRANGEMENT OF STORES GANGWAYS

to be stored, and shelves should be arranged to take the working loads with a good margin of safety.

Storage Bins. The design of storage bins varies considerably. Due consideration must always be given to

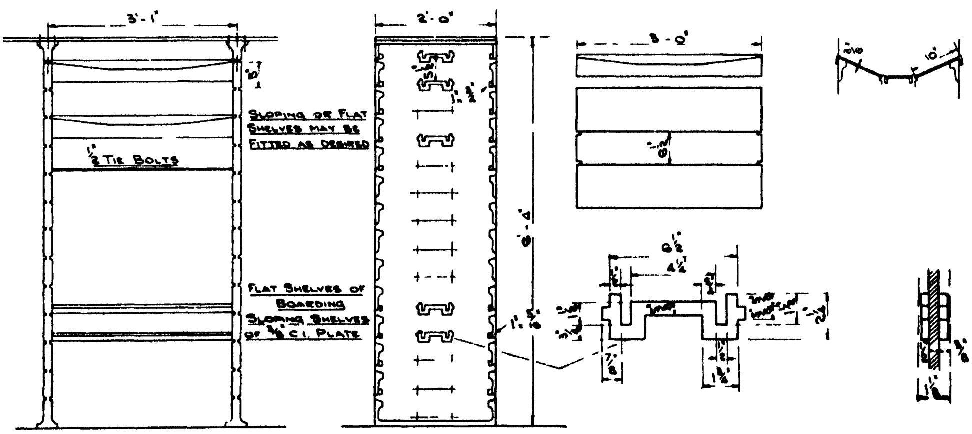


FIG. 314. STORAGE RACK

the strength, carrying capacity and durability of the type or types decided upon. Fig. 314 shows an extremely useful type with cast-iron sides and cast-iron or wooden shelves according to preference. Fig. 315 shows the suggested layout for a complete installation of steel storage bins, but of a different type. Tapered bins, with narrow shelving at the top and wide shelving at the bottom, are very suitable for the storage of a large range of articles of varying dimensions such as files, drills, bolts, nuts, etc., where the larger sizes can be accommodated in the lower bins and the smaller sizes at the top. They are also advantageous where the space available for gangways is limited, as the gangway widens out where elbow room is required.

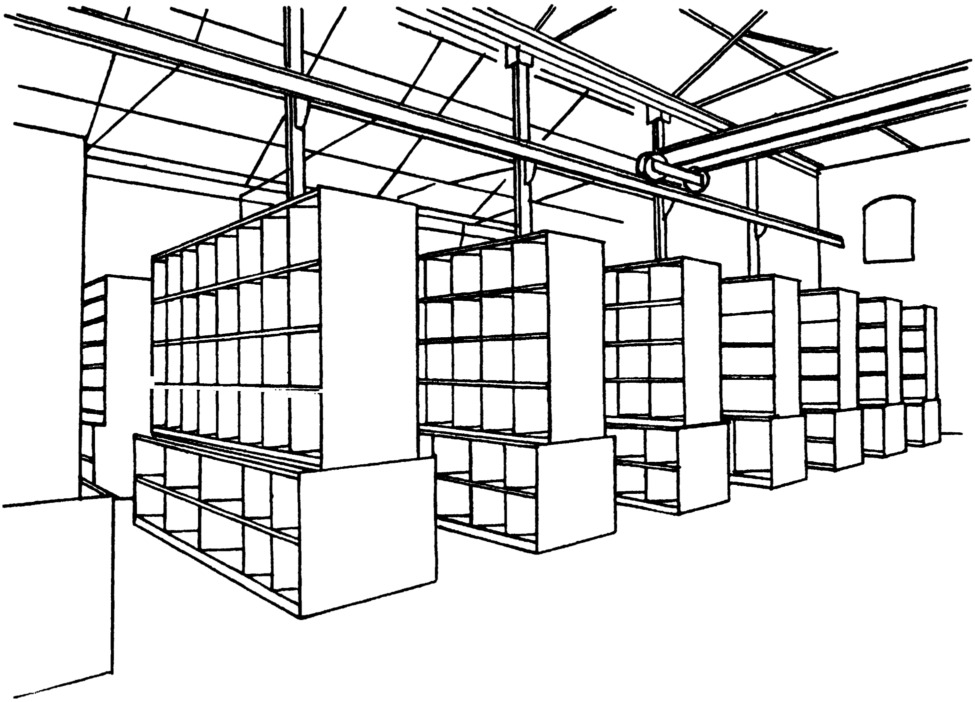


FIG. 315. INSTALLATION OF STORAGE BINS

Open Type Shelving. Many articles by reason of their weight, shape, or size cannot be suitably accommodated in bins, and in such cases open type steel shelving, Fig. 316, is recommended. This type of shelving consists of angle posts, shelves and sway braces, and is the simplest and most suitable type where goods are to be stored in fair size boxes, bundles, or large pieces. The uprights should be pierced at 2 in. centres, allowing for shelf arrangement to suit individual requirements.

Closed Type Shelving. Closed type shelving, Fig. 317, is constructed by substituting sheet backs and uprights

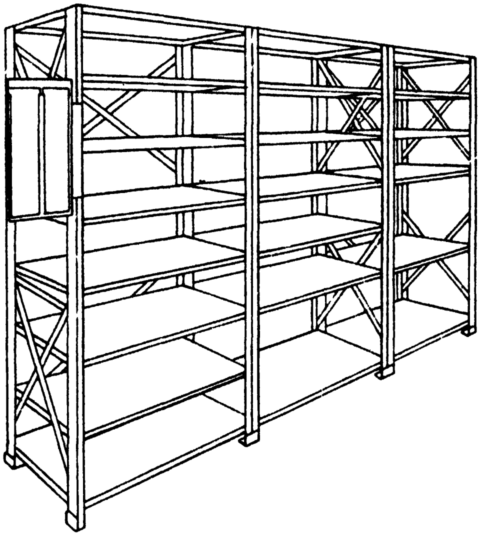


FIG. 316 OPEN TYPE STEEL SHELVING

FIG. 317 CLOSED TYPE STEEL SHELVING

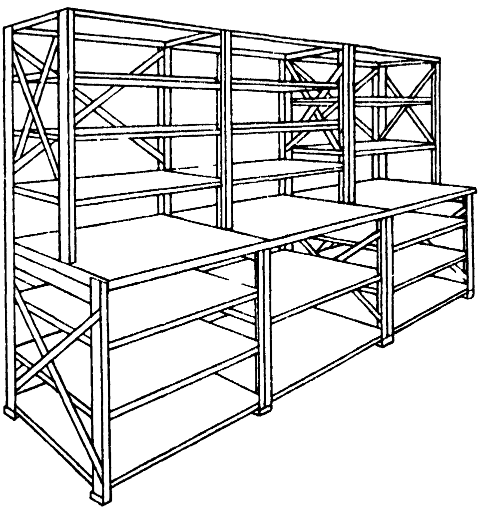


FIG. 318 OPEN LEDGE TYPE SHELVING

FIG. 319 CLOSED LEDGE TYPE SHELVING

for the sway braces employed with open type shelving thus the whole structure is sheeted in or closed. The addition of bin fronts provides compartments specially suitable for the storage of small parts.

Open Ledge Type Shelving. This is similar to the open type except that the bottom section is of greater depth than the upper section (Fig. 318), providing a very useful working surface, upon which goods can be rested, parcelled, and counted.

Closed Ledge Type Shelving. This

type, illustrated in Fig. 319, is made by substituting sheet backs and uprights for the sway braces used with the open ledge type. The addition of bin fronts makes compartments particularly suitable for the storage of small components.

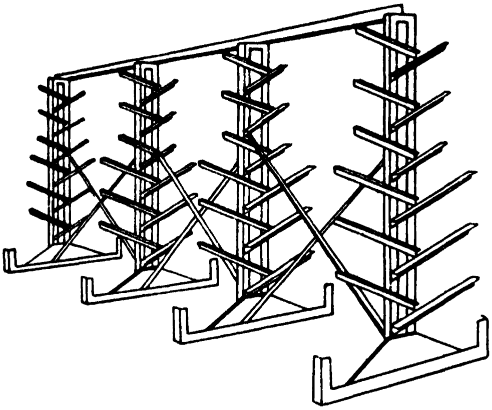


FIG. 320 GANGWAY RACKS

Gangway Racks. Gangway racks, Fig. 320, occupy the minimum of floor space, and should be so arranged that material can be brought alongside and transferred direct on to the adjustable carrier bars from the gangway. No loading bay at the end of a gangway rack is required, and the resulting economy of floor space will be appreciated by all who are concerned with workshop layout. When a gangway rack is required to carry very heavy loads the uprights should be spaced closer together.

Vertical Rod and Bar Racks. These racks, illustrated in Fig. 321, enable full advantage to be taken of height. They can be designed to accommodate any weight of material, and adjustment facilities provided to meet varying stock requirements. This type of rack is usually built on the unit and extension principle, the size being determined by the stock to be carried. Each rack has a tray built into its base, in which the stock stands. The

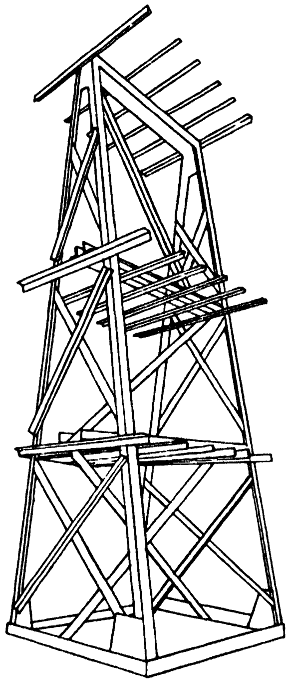


FIG. 321 VERTICAL ROD AND BAR RACKS

purpose of this tray is to retain surplus oil draining off the rods or bars when stored.

"Offcut" Rack. This is a most useful type of shelving, as it draws attention to the existence of "offcuts" in varying lengths, from which a suitable piece can be selected immediately. In this way short lengths become used, and waste is avoided.

Standardization. Considerable economy can be effected by keeping the dimensions of the shelving constant throughout the installation. This will

enable future rearrangements to be made more quickly and easily.

Ceilings. It is not advisable to run the shelving right up to the ceiling if this means a variation in heights to avoid beams, pipes, etc. A better plan is to adhere to a standard height throughout, and to make use of filler panels up to ceiling height.

Ladders and Climbing. It should be remembered that in cases where the shelving is more than 7 ft. high it may be necessary to provide ladders or some other means of reaching the upper compartments. Travelling ladders, Fig. 322, have much to commend them. The wheels at the base should be rubber tyred, giving ease of movement combined with noiselessness. Support should be provided at the top by means of grooved wheels which travel on a steel runner bar attached to the shelving.

Sprinkler Systems. Where sprinkler systems are installed the top shelves should be kept clear of the sprinkler heads, and an allowance for clearance should be made in accordance with official regulations.

Identification of Iron and Steel Bars

The various grades of iron and steel bars, etc., should be indicated by having the ends of the bars painted. The colours used should be in accordance with the British Standard Shades, the appropriate colours being applied to the iron and steel at the stores depot on receipt of the material from the contractors. The colouring should be carried out with synthetic resin enamels. These are fadeless, are not liable to collect dust, and when wiped will retain the original colours.

Stores Catalogue

The preparation of a stores catalogue for internal use requires considerable forethought. Fig. 323 gives

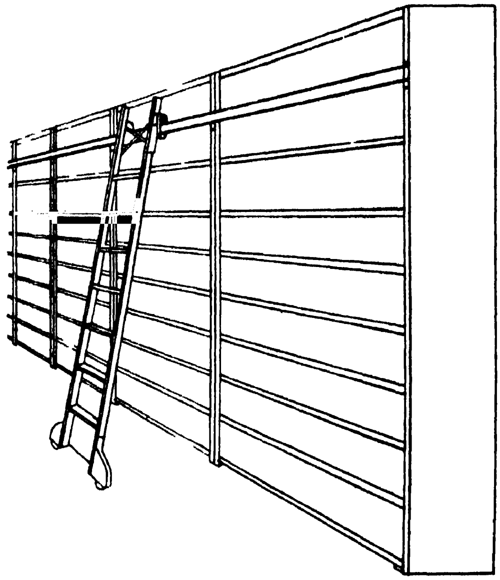


FIG. 322 TRAVELLING LADDER

suggested classifications, a separate prefix number being given for each section. The manner in which each item should be described in the catalogue is shown in Fig. 324. Where desired the "Remarks" column can be filled in by those using the catalogue in order to indicate for what purpose the parts are required.

Stores Requisitions

When items which are chargeable to workshop expenses are required, they should be ordered from the stores on a stores requisition, a suitable form for this purpose being shown in Fig. 325.

STORES CATALOGUE

Index of Classifications

	Prefix Number
Abrasives	1
Asbestos	2
Bolts, Nuts, and Washers	3
Bricks, Slates, Stone	4
Brushes	5
Cables, Electric	6
Chemicals and Drysaltery	7
Electrical Equipment (General)	8
Gas, Steam, and Water Fittings	9
Glass and Glassware	10
India Rubber	11
Ironmongery	12
Iron Bars	13
Iron and Steel Castings	14
Iron and Steelwork, Fabricated	15
Lamps and Fittings	16
Leather and Belting	17
Miscellaneous	18
Non-ferrous Castings (Rough)	19
Non-ferrous Castings (Finished)	20
Non-ferrous Metals and Bars	21
Oils and Greases	22
Paints and Varnishes	23
Pins and Cotters	24
Rivets and Studs	25
Road Motor Accessories	26
Ropes (Wire) and Chains	27
Scrap Materials	28
Screws, Nails, and Staples	29
Steel Bars	30
Textiles	31
Timber, Fabricated	32
Timber, Unfabricated	33
Tools and Implements	34
Tubes, Steel	35

FIG. 323. CLASSIFICATION OF STORES CATALOGUE

Catalogue No.	Item	Description	Size	Unit of Issue	Remarks
3/2500	Set Screws	Set Screws, Whitworth Thread, Steel, Specification 15. Grade 1, Black, or Merchants' Equivalent Quality, Hexagon Head.	1 in. × $\frac{5}{16}$ in.	Gross	
3/2501	,,	Do.	$\frac{5}{8}$ in. × $\frac{3}{8}$ in.	,,	
3/2502	,,	Do.	$\frac{3}{4}$ in. × $\frac{3}{8}$ in.	,,	
3/2503	,,	Do.	$\frac{7}{8}$ in. × $\frac{3}{8}$ in.	,,	
3/2504	,,	Do.	$1\frac{1}{2}$ in. × $\frac{3}{8}$ in.	,,	

FIG. 324. ARRANGEMENT OF CATALOGUE

DEMAND FOR GENERAL STORES

... 19 Dept. Reg. No. **50**

Description		Last Supply		Quantity on hand	Quantity Required	These Columns to be left blank for Departmental Use										
						Supplied					Date Supplied	Rate	Unit	Amount		Remarks
Catalogue No.	Article	Quantity Supplied	Date Received			Quantity	T	C.	Qr.	Lb				£	s. d.	

Approved by

FIG. 325 STORES REQUISITION

STORES LEDGER

WEEK ENDING 11TH MAY, 1940

Catalogue No.	Unit of Issue	Balance		Receipts		Issues	
		Quantity	Amount	Quantity	Amount	Quantity	Amount
(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
			£ s. d.		£ s. d.		£ s. d.
253	01	101·00	2 10 6				
		30·00	15 0	14·00	7 0	85·00	2 2 6
258	01	28·00	3 17 1				
		63·00	8 11 0	49·00	6 10 8	14·00	1 16 9

SURPLUS MATERIAL

Date *11th March, 1940*

Catalogue Number	Date of last Issue	Exact Description and Full Dimensions of Material	Condition	Supplied	Purpose for which Ordered	Reference to Contract Item or Special Purchase where Available	No. of Articles	Weight T. C. Qr Lb	Price on Books	Value on Books £ s d	Disposal Code*	Remarks
34/2442		*Inspection Gauges*	*Good*	*193*8	*Inspection Dept*		*10*	– – – 8	*10s. each*	5 0 0	*C*	

* **KEY TO DISPOSAL "CODE"**

A. Can be utilized in....... ..... months. (Time to be stated thus—A 9.)
B. Saleable or transferable Stores (other than those included under "A" and "C").
C. Obsolete Material.
D. Saleable as scrap only.
E Of no scrap value.

FIG. 327. SURPLUS MATERIAL FORM

Stores Ledger

This should be compiled weekly by means of tabulating machines, Fig. 326 indicating the form which the ledger should take. On considering the first example it will be seen that Catalogue No. 253 (Column A) is issued in single units (Column B). At the beginning of the week there were 101 in stock (Column C top line) valued at 6d. each. During the week, however, 85 are issued (Column G) and 14 more are received (Column E), these transactions giving a credit balance of 30 (Column C bottom line).

Surplus Material

There will be occasions when material or equipment already in stock or progress will not be required. In this instance a form drawn up on the lines indicated in Fig. 327 should be prepared by the stores department and the appropriate action taken. By so doing systematic attention will be given to the disposal of obsolete or surplus stocks.

Material on Delay

Whenever requisitions for parts cannot be met immediately by the stores, the works should be advised by means of a "Material on Delay" form, Fig. 328. If this form is supplied in duplicate one copy can be returned to the stores department showing the anticipated date of completion in Column H.

Verification of Stores

Periodically—perhaps once a year—it will be deemed necessary to take account of the stock in hand. This will necessitate special arrangements being made, the most suitable period for stocktaking generally being during the works annual holiday. A separate card, Fig. 329, should be used for each item recorded.

MATERIAL ON DELAY *16th March,* 1940

Cat No.	Description	Stock Order No	Stock Order Date	Stock Order Qty.	Required for	Qty Owing	Promise of Delivery
(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
CLASSIFICATION 34							
34/32840	Spanners, Closed	1/1242	22/2/40	20	Stock	3	
34/30206	Scrapers	1/8821	12/2/40	40	,,	15	

FIG. 328. MATERIAL ON DELAY FORM

VERIFICATION OF STORES.

No. 50503

STORES RACK No BIN No

DESCRIPTION.—

CATALOGUE			
Class'n.	Prefix	Number	Unit

Condition and Class of Material	Total No. in Stock	Weight each	Initialed	Total Weight	Quantity or Weight in Unit of Issue	Rate	Amount

FIG 329 CARD FOR VERIFICATION OF STORES

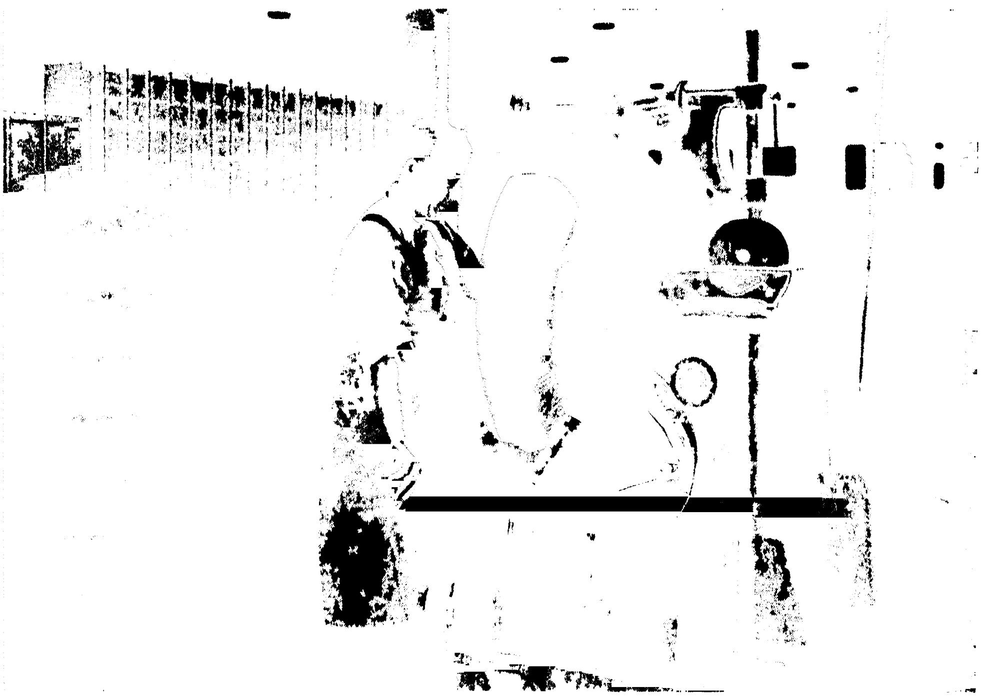


FIG 330 TYRE WRAPPING MACHINE IN WAREHOUSE

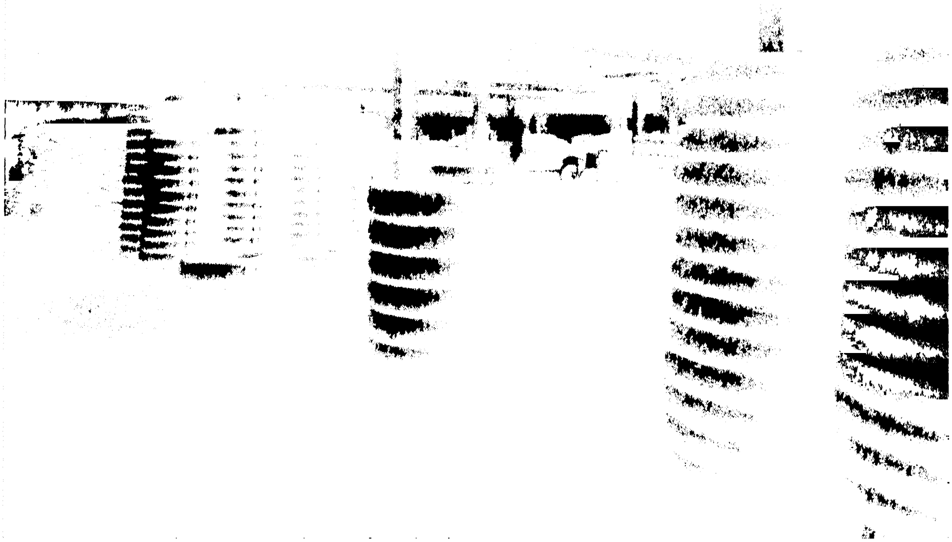


FIG. 331 STORAGE OF TYRES IN WAREHOUSE

FIG. 332 DISPATCH OF TYRES FROM WAREHOUSE

Warehouse

Closely allied to storekeeping is the maintaining of warehouse stocks of both the completed articles and spare parts ready for distribution. The relevant principles already explained can be adopted with good effect in the warehouse. The latter will form part of the sales department, but is mentioned here for convenience. The only additional feature is that any packing which may be necessary should be efficiently carried out, otherwise damage will almost certainly occur during transit. Figs. 330, 331, and 332 symbolize the work of an efficient warehouse.

CHAPTER XXX

SALES ORGANIZATION AND TENDERING

A MANUFACTURER, distributor, or retailer may employ high-salaried officials to direct his business and he may staff his organization with the best creative, merchandising, and advertising brains, yet it has to be conceded that his ultimate success is largely in the hands of his sales organization.

Unlike the production department, the sales department is faced with the difficulty that it cannot be effective within its own personnel, the most perfect team work being of no avail unless the prospective customer or market can be influenced to the extent of becoming and remaining a buyer.

Responsibilities of the Sales Manager

In a typical firm, the responsibility for sales normally devolves upon the sales manager. The usual functions of such an officer include the supervision of outside representatives, their appointment and training, the control of the head office sales staff, the fixing of prices and discounts in consultation with the general management, the approval (for the sales side) of production programmes, the control of any outside service provided, and responsibility for publicity and advertising. In these circumstances, it is not surprising that there is a tendency for sales managers and their staffs to concentrate on their own departmental routine and deal only with regular customers, thus failing to inspire the design and production departments to meet the demands of the market, and only occasionally and intermittently dealing with the promotion of new business. This latter deficiency suggests the need for a separate sales promotion section.

A comparatively low price is, of course, the most convincing single argument to obtain a customer, yet with engineering products this advantage is exceedingly difficult to secure, still more to maintain, and it is not feasible to organize for selling on such a basis alone.

It will be convenient to classify the influences affecting sales under three heads

(1) The reputation of the manufacturer.

(2) The merits of the product.

(3) The effectiveness of the salesmen.

Manufacturer's Reputation

If the reputation of the manufacturer is to become a conscious influence on potential customers, there must be organized publicity. Until firms are well known, information regarding them receives but scant attention, and a prominence that is only temporary may on its cessation imply an eclipse. Organized publicity will take various forms, of which Press publicity may be the most obvious but not necessarily the most important. Alertness

and eagerness to serve must be evident on all occasions and at all points, and there must be meticulous attention to detail, because every prospective customer judges from his own experiences and is unfavourably impressed by what may seem, to those who make them, insignificant slips.

The building up of the manufacturer's prestige will involve many issues, these including—

(1) Activity in public affairs.

(2) Efficiency in tendering.

(3) Dependability of after-sales service.

(4) Reliability of delivery promises.

(5) Helpfulness in handling complaints.

(6) Intelligence in control of credit.

(7) Liberality in interpreting guarantees.

(8) Promptitude in correspondence.

(9) Receptivity to suggestions.

(10) Making technical literature attractive.

Merit of the Product

To the prospective purchaser the merit of the product will depend on many considerations, although the help of the salesman is nearly always necessary to ensure that appropriate emphasis is given to the merits which will appeal to a particular customer.

Technical merit is of various forms. It may be a merit of performance, having relation to high duty rather than to long life, or to efficiency rather than to economy. It may be a merit of accuracy, which may be primarily a matter of performance, as, for instance, in a jig-boring machine, but is of little value except in association with durability. There are other kinds of technical merits but they are chiefly matters of design and workmanship consistent with the price at which the product is offered. To sum up, it is difficult to make comparisons between products which differ both in price and construction, and it is desirable to formulate some sort of equation which will measure the respective merits of competing products. It is possible to do this satisfactorily regarding economic merits, but technical merits can only be established by data of performance so presented as to carry conviction of superiority. In this connection, it should be borne in mind that impressive pictorial illustrations of products in use have a universal appeal. Much, too, may depend on evidence of sales to well-known firms, whose own reputation tends to confirm the claim for any product they may select.

Budgetary Control

As all net profits must come from sales, and in view of the fact that productive activities in well-organized factories are already quite adequately controlled, the applying of budgetary control methods to selling and to distribution costs assumes outstanding importance.

Assuming that sales quotas can best be fixed by establishing sales districts, in each of which an individual salesman is active or in which some other distinct method of selling has been adopted or planned, one is confronted with the necessity for information on the following general questions –

(1) What was accomplished in the past period?

(2) What mistakes were made in the past?

(3) What are the proper ways and means of correcting these past mistakes?

(4) What is the present status with regard to sales possibilities?

(5) What methods must be adopted to convert these sales possibilities to actual orders?

(6) How may the orders best be secured, and in what seasonal sequence?

(7) What has been the record of advertising, both locally and nationally?

(8) What changes may be advantageously made in advertising—in the medium, form, and appearance—so as best to aid in the local field work?

(9) What plan shall be devised for daily, weekly, and monthly check-up on sales accomplishments and distribution costs?

(10) What shall be the basis for judging the relative efficiency of salesmen operating under like or closely similar sales conditions?

Technical Literature and Publicity

It is futile to argue for a standardized scheme of functionalization within every sales department, because the requirements of each case vary so much owing to differences in policy, products and personnel.

One function that can safely be mentioned, however, is that of editing technical data and literature. Part of this work might be the preparation of loose leaf manuals or data books for salesmen's use. Working instructions in particular should be subject to competent editing before issue.

The use of illustrated folders for salesmen, for direct-mail circulation and for catalogue building, is hardly less important than that of Press advertising. Exhibitions are another form of publicity. There is, too, the circulation of information which is of sufficient interest to be reproduced in the editorial columns of the general and technical Press.

In connection with the selling of technical products particularly, correspondence is a function calling for a skilful organization of records of relevant information, such as past communications and transactions, business connections, and credit standing.

Tendering

Closely allied to correspondence is the function of tendering, by which a price is offered without reference to a standard price list. A study of the tenders received from various firms in response to the same inquiry often reveals surprising differences both in presentation and price. It should always be borne in mind that those which are drawn up in the most convincing yet co-operative manner are likely to receive the most consideration even though they do not represent the cheapest quotation.

Tendering will frequently involve responsibilities too onerous for the sales manager to carry alone, and, in such cases, the assistance of the estimating department will be required. Tendering does, in fact, call for the closest possible collaboration with the estimating department, as

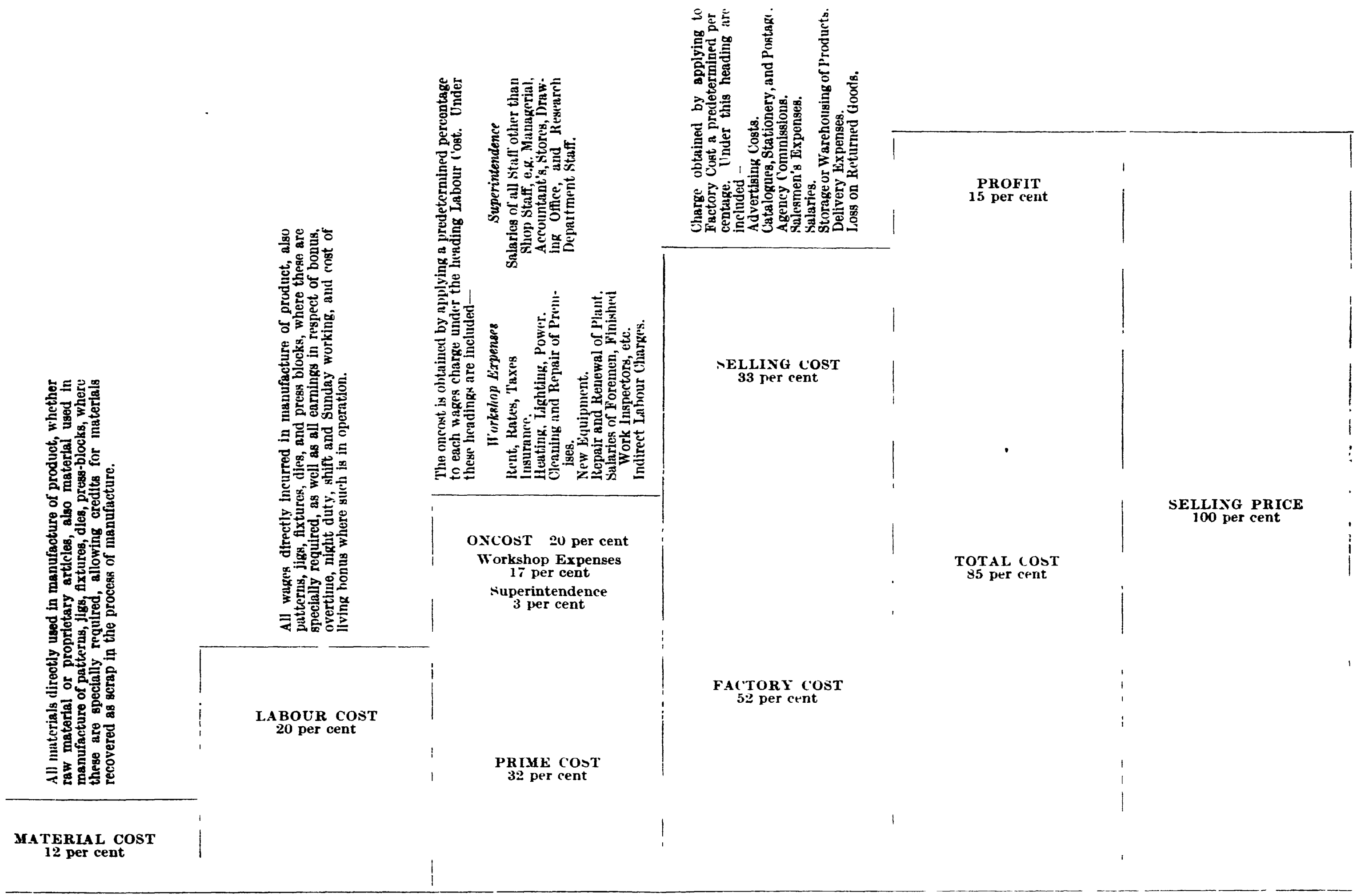


FIG. 333. TYPICAL EXAMPLE TO ILLUSTRATE COMPOSITION OF SELLING PRICE

it is important that the maximum technical insight be brought to bear as quickly as possible on each inquiry and specification received; essential information may be missing, quotations may have to be obtained from other manufacturers, and conditions of contract may be unduly onerous. Where a specification is not furnished, and one has to be prepared, a standardized practice should be followed so that no items or contingencies are overlooked.

Although in the production of every item there is a certain maximum quantity beyond which the factory cost cannot be reduced, it does not follow that the selling cost will also remain constant. On the contrary it sometimes happens that it is uneconomical to produce beyond a given quantity on account of the comparatively heavy cost involved in finding a market. To meet price competition, alternative specifications on cheaper lines may be advisable, when possible, to throw into relief the superiority of the higher price offer.

In tendering, any promise regarding delivery requires to be based on an analysis of the work called for, in the light of experience and current conditions, and is therefore a matter for an intelligent use of records and conference with departments that would be affected if the contract were obtained.

The final phase of any tender is the determination of the price to be quoted. It would seem only right to approach price-fixing as a logical process of first estimating the total production costs, and adding thereto margins to cover selling expenses (on the basis of experience in the particular market), average administration or general charges, and net profit, respectively, thus arriving at what may be called an "economic" price.

Reference to Fig. 333 will assist those concerned to arrive at both a logical and competitive selling price.

There can of course be no permanent prosperity unless contracts or orders in the aggregate will meet all costs and provide a net profit. Whatever sacrifice may seem politic to obtain a particular contract, it is in the first place always advisable to adhere to the analytical method of building up the economic price. With standardized products, price-fixing on any other than an economic basis is full of risk because losses on a unit price will be multiplied.

Method of Tendering

It will be instructive to give two distinctly different examples.

Example 1. On page 110 (Chapter VII) is reproduced a typical "master" inquiry from a firm desirous of purchasing two planing machines. It may be assumed that the following answer is representative of several replies received by the prospective purchaser from different firms -

10th July, 1940.

To Messrs. Turnbull, Winfield & Co., Ltd.,
Derby.

Dear Sirs,

<u>Two Tandem Table Planing Machines</u>

In reply to your inquiry, Ref. L/W.423, we have pleasure in quoting you herewith, and hope to be favoured with your esteemed order, which shall have our prompt and careful attention.

Price: £1620 each.
Terms: Per our Conditions of Sale.
Place of Delivery: Littleover.
Time of Delivery: Four to six months from receipt of order, subject to strikes, lock-outs, accidents, and other unforeseen contingencies.
Description: Two Planers (Type P4) with Tandem Tables and our standard Single Helical Keyless Driving Gears and Rack, to the following particulars—

To plane in width and height . . .	40 in. × 36 in.
To plane in length .	16 ft.
Dimensions of each table . . .	8 ft. × 3 ft. 6 in.
Cutting speeds proposed . . .	60/200 ft. per min.
Return speeds independently variable	200/250 ft. per min.
Feeds . . .	$\frac{1}{64}$ in., $\frac{1}{32}$ in., $\frac{3}{64}$ in., $\frac{1}{16}$ in., $\frac{3}{32}$ in., $\frac{1}{8}$ in., $\frac{3}{8}$ in., $\frac{3}{4}$ in.

Approximate weight 20 tons.

Each machine to be complete with two heads on cross slide, one head on each upright, 50 h.p. patent split field drive, electric feeds, power traverses, and independent solenoid tool relief to each head as described in the accompanying specification. The machines conform to General Arrangement Drg. No. 2825, copy enclosed, and all materials will be of British manufacture throughout.

Your A.C. and D.C. questionnaire forms have been duly completed and are returned herewith.

Yours faithfully,
For E. Goodhead & Sons Ltd.,
(Signed) M. Mansfield.

The planing machine illustrated in Fig. 334 conforms to the stated requirements and the detailed specification to accompany the tender might read as follows—

SPECIFICATION

STRUCTURAL

The Bed rests on the ground for its full length. It is of unique design, with continuous top plate in place of the usual box bars, except at the point where the gearing is accommodated. Here the side walls are doubled to withstand the driving strains.

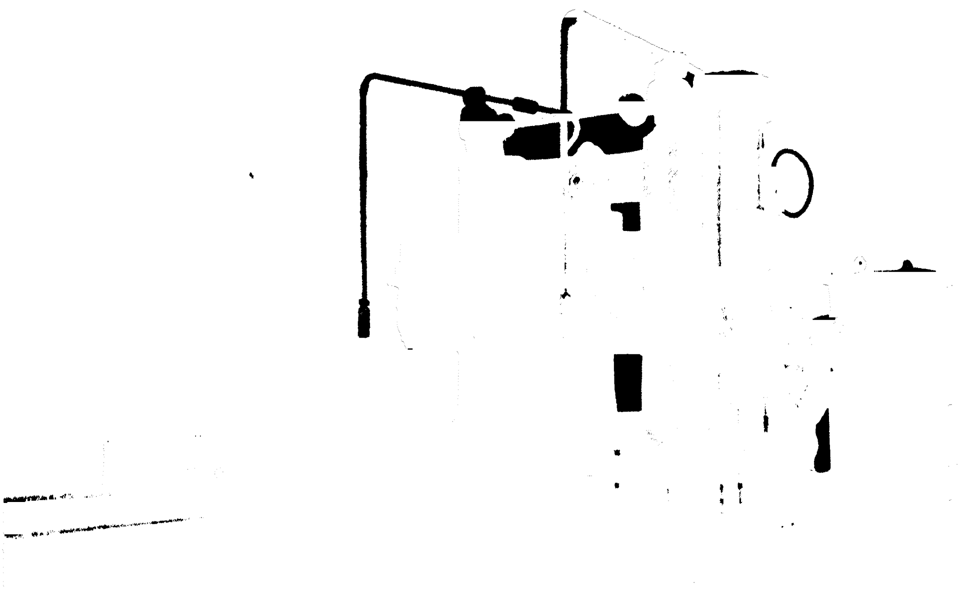


FIG. 334. TANDEM PLANING MACHINE

Numerous cross ribs combine with the double sides and continuous top plate to make the most rigid bed possible.

The Table is of a special box type, with tee slots and stop holes in the top plate, and openings in the side to remove cuttings.

The Housings are tongued, keyed and bolted to the sides of the bed, and securely tied together at the top by deep cross rail. They are of great depth from back to front and of robust design.

The Cross Slide is of strong section, with substantial deep fish back to resist the various strains to which it is subjected.

The Two Heads fitted to the cross slide consist of tee-slotted clapper tool boxes, hinging and lipping on to special quadrants. These are each mounted on a long swivel slide, which in turn is secured to an indexed base slide, or saddle, by bolts located in circular tee-slotted race.

Side Head of similar design is usually fitted to the near housing, and a fourth head on the far housing is furnished when specified.

Driving Gear, including rack, is all of steel. Pinions are forged solid with shafts; medium size gears are from single piece forgings or castings; large wheels have weldless steel rings shrunk on cast iron centres, and racks are from solid forged slabs.

Machining and Fitting

Sliding Ways of bed and table are accurately planed, and carefully hand-scraped to each other. Extreme precision is ensured by the use of a special instrument, when aligning the bed for erection.

Heads, Cross Slide and Columns are similarly prepared, and adjustable strips provided for all slides and wearing parts.

Journals are truly bored and, where necessary, are bushed with gun metal, or fitted with ball or roller bearings.

Shafts and Screws are turned or ground, and threads cut in lathe, or milled, according to the needs of the individual case.

Gearing is all machine-cut from the solid, of steel where necessary and where specified, and entirely keyless. It is principally generated on patent gear planing machines, but for certain details other processes are employed.

Functional

Transmission from reversing motor is by keyless steel helical gears and rack, giving the smoothest possible table movement and maximum efficiency.

Patent Electric Quick-change Feeds are provided, readily variable and reversible, precise and instantaneous in action. The range covers for all possible requirements in stock removing, and in addition extra broad feeds are available for finishing cuts.

Original Electro-magnetic Tool Lifting Device is fitted to each head and any one may be switched off separately if desired.

Patent Power Traverses are given to all the heads by supplementary motor, which may be readily coupled to any motion by conveniently located selector clutches. Quick and fine rates are available, the latter enabling cuts to be set in without the use of handles.

Elevation of Cross Slide is also accomplished by the supplementary motor.

Hand Movements are provided to all heads in all directions, and side heads are carefully balanced.

Locking Devices enable the cross slide to be rigidly secured in any desired position, and the various slides to be firmly locked, according to the direction in which cuts are being taken.

The Drive is by our patent split field reversing motor equipment, which is suitable for either alternating or direct current. The apparatus comprises—

Motor Generator fed from the main supply, and delivering variable voltage current of changing polarity, according to the section of the generator split field in use.

Reversing Motor, flange type, with heavy and light section shunt fields, both sections being connected in agreement for the slow cutting speeds, and the light section only being employed for quick return speeds.

Supplementary Motor for feeds, power traverses, and elevating cross slide, with special patented features for dealing with these various functions.

Switchgear consists of—

Primary Motor Starter for motor of motor generator set.

Main Panel containing two shunt regulators to give independent variation to cut and return speeds, and two contractors only, for cut and return speeds respectively. This panel also embodies series regulator and two sets of contractors for the supplementary motor, one for each direction of rotation, and special contractor to give step by step motion to the armature, when actuating feeds.

Accelerating Switch to speed up table on cutting stroke, either in metal or between surfaces.

Universal Safety Trips to prevent collision between heads and cross slide.

The Control is arranged to give the utmost facility in handling the machine to the best advantage.

The Stroke for table is controlled by patent disc and master switch. Setting is accomplished without the use of spanners, and graduations on the disc enable alterations of a few inches or a few feet to be made readily.

Balanced Swivelling Pendant Switches are provided, one on each side of the machine, embodying push buttons to start, stop, and inch the table, and to actuate the power traverses. This system constitutes duplicate, flexible, and centralized control.

GENERAL

Automatic Lubrication is provided for the sliding ways and bearings, by a pump and generously proportioned oil tank. Arrangements are made alongside and at each end of the bed to catch waste oil. Driving gears are splash lubricated, overhead parts are oiled by "one-shot" pump, and dust-proof nipples fitted to points requiring individual attention.

Gear Guards are furnished in all cases where the design does not provide inherent protection.

Testing. The machine is run and tested under its own equipment in our works before despatch.

Accessories. The machine is complete with three heads, all handles, spanners and two ordinary drop forged tool holders for each head, also complete electrical equipment as described, together with wiring diagram and instructions for installation and operation.

On the assumption that this particular quotation is accepted, a reply on the lines of the following should be sent by the purchaser to Messrs. E. Goodhead & Sons Ltd. —

Dear Sirs,

Two Tandem Table Planing Machines

Referring to your letter of 10th July, 1940, and your quotation included therein, you are hereby accepted to supply and deliver—

Two Planing Machines, Type P4, with Tandem Tables and helical driving gears. To plane in width 40 in., height 36 in., length 16 ft., each table 8 ft. × 3 ft. 6 in., cutting speed 60 to 200 ft. per minute, return speeds 200 to 250 ft. per minute. Machines to be fitted with two heads on cross slide and one head on each upright. Solenoid tool relief to each head. Machines to be complete with patent split field drive and all electrical equipment as quoted. Primary motor to be suitable for 440 v. 3-phase 50 cycles.

For the sum of £1620 each machine, or a total sum of £3240 (Three thousand, two hundred and forty pounds) for the two machines.

Please consign the machines carriage paid in four to six months from receipt of this order to our Works at the above address.

All electrical equipment and tests are to be to the satisfaction of our Plant and Machinery Engineer, and the equipment is to be supplied to I.E.E. Conditions, except as varied by the specification. Before any electrical work is put in hand or orders placed by you on sub-contractors, approval must first be obtained as to technical details and conditions affecting electrical work.

We shall be obliged if you will kindly send an acceptance of this order in writing to this Office.

Yours faithfully,
S. M. Bates.

Example 2. In this case let it be assumed that a tender is being submitted for the equipment required in the laying out of the mechanized non-ferrous foundry illustrated in Fig. 17, Chapter III. Such a tender will probably be submitted in the following form

13th September, 1939.

To Messrs. R. H. Levers & Co. Ltd.,
Hanley.

Dear Sirs,

Proposed Mechanization of Non-Ferrous Foundry

With reference to your letter of the 1st March, returning the copy of our questionnaire respecting the layout of your new

Foundry, and to our subsequent correspondence on this subject, we have now much pleasure in sending you herewith a complete specification of the various units making up the plant required for installation in your Foundry.

We also send herewith Drawing No. FM/2724 showing the general arrangement of the plant as we would propose to construct it. In the event of our quotation being accepted we will supply you with one complete set of detail drawings.

Our price for the erection of the total equipment on foundations to be prepared by you, the services of skilled erectors to be supplied by us, and all necessary unskilled labour to be provided by you, is £750.

Our price does not include the cost of motors, switchgear, or any electrical equipment whatsoever. We can, of course, obtain details and prices for this electrical equipment on hearing further from you that you are in agreement with the general scheme and the prices shown.

TERMS OF PAYMENT

33⅓ per cent with the order.

33⅓ per cent against delivery of each item or part of plant.

23⅓ per cent against erection and starting up of plant.

10 per cent one month after starting up.

Erection charges to be paid against completion of erection.

Our estimated time for completion is five to six months from receipt of order.

We have not included a price for the moulding machines because you have not stated which type of machine you will employ, apart from your considering the installation of some of your existing machinery into this layout.

All prices shown in this estimate are strictly net and are not subject to any discount.

We have recently been advised that there is every possibility of a large increase in the price of conveyer belting in the near future, and all the above prices are, therefore, subject to any market fluctuation and to early acceptance by you.

We hope to be favoured with your esteemed order which shall have our best attention.

Yours faithfully,
(Signed) M. H. Taylor,
Sales Manager.

SPECIFICATION

PLANT FOR MECHANIZED FOUNDRY

Price

Item 1. The KNOCKOUT GRIDS would consist of 2 in. × $\frac{5}{16}$ in. bars and ¾ in. × $\frac{5}{16}$ in. bars at 1½ in. mesh in small sections for easy removal. These grids would be in the centre line of the trench with ¼ in. thick chequer plating on each side. The CHUTE to the conveyer would be ⅛ in. thick and complete with continuous rubber skirting the entire length of the conveyer. £550

Item 2. 18 in. TROUGHED BELT, 210 ft. centres. The BELT would be of heat resisting quality rubber 4-ply with $\frac{3}{32}$ in. and $\frac{1}{16}$ in. covers. The idlers would be mounted on ball bearings, the top idlers being of the troughed type, suitably spaced to take uneven loading. The return idlers would be of the flat type, spaced approximately 10 ft. apart. The drive would be through bush roller chain and totally enclosed worm reduction gear. All shafts would be of suitable strength and mounted on ball bearings. The framework would be built up of 4 in. × 2 in. channels with all necessary supports to give rigidity. A 3 h.p. motor would be required to drive this unit. £750

Item 3. Consists of ¼ in. CHEQUER PLATING covering the belt for Item 1. £50

Item 4. 18 in. TROUGHED BELT, 25 ft. centres. This conveyer would be of similar construction to Item 2, but a 2 h.p. motor would be required to drive. £130

Item 5. 7 in. BELT AND BUCKET ELEVATOR, 33 ft. centres. This elevator would be designed to handle 6 tons of sand per hour. The belt would be 8 in. wide × 5-ply with $\frac{1}{16}$ in. covers of heat resisting quality rubber, running over 22 in. and 20 in. top and bottom drums, the latter being of the cage type. The drive would be through machine-cut spur and chair gearing mounted on shafts of ample dimensions, which would in turn run in ball bearing plummer blocks. The casing would be of the totally enclosed type built up from ⅛ in. steel

	Price
plates and $1\frac{1}{2}$ in. × $1\frac{1}{2}$ in. corner angles. The buckets would be 7 in. long × 11 g. thick, complete with thickened lip, and completely galvanized. A 3 h.p. motor would be required to drive this unit.	£165
Item 6. ONE ROTARY SAND SCREEN. This screen would be made from $\frac{3}{16}$ in. thick wire of $\frac{1}{2}$ in. mesh, mounted on two cast-iron end discs with malleable iron arms. The whole would be supported on mild steel shaft, running in ball bearing plummer blocks. The drive would be through spur gearing and worm reduction gearing and would be driven by a 2 h.p. motor. The screen would be suitably enclosed in $\frac{1}{8}$ in. thick sheet steel casing with rapping device, fitted to clean the mesh. A chute would be provided to discharge tailings at floor level.	£110
Item 7. 5 ton SAND STORAGE HOPPER. This hopper would be of the round tapered type built from $\frac{3}{16}$ in. steel plates and would be complete with supporting structure platform and access ladder.	£75
Item 8. ONE ROTARY DISC FEEDER, 6 ft. 5 in. dia. The feeder would consist of a vertical worm reduction gear box with a mild steel disc 6 ft. 5 in. dia. mounted on the top. An adjustable plough would be provided to take the sand from the disc to the pan mill. A 3 h.p. motor would be required to drive this unit.	£110
Item 9. ONE S.B.1 SAND MILL. (Please see our Catalogue for description.)	£595
Item 10. ONE 16 in. BELT under pan mill, 28 ft. centres. This belt would be of similar construction to Items 2 and 4 except that the top idlers would be flat. A 2 h.p. motor would be required to drive.	£105
Item 11. This would consist of $\frac{1}{4}$ in. CHEQUER PLATING to cover the pit for Item 10.	£42
Item 12. ONE 7 in. BELT AND BUCKET ELEVATOR, 25 ft. centres. This elevator would be generally similar in construction to Item 5. A 2 h.p. motor would be required to drive.	£125
Item 13. SUPPORTING STRUCTURE FOR DISINTEGRATOR. This structure would be of rigid construction and complete with a discharge chute underneath to Item 15. The countershaft would be mounted on the ball bearing plummer blocks attached to the frame and would be complete with three cast-iron pulleys.	£55
Item 14. ONE SAND DISINTEGRATOR. (Please see our publication on Sand Preparation—page 4, for complete description.)	£125
Item 15. ONE 16 in. INCLINED BELT CONVEYER, 40 ft. centres. The belt would be 4-ply with $\frac{3}{32}$ in. and $\frac{1}{16}$ in. rubber covers running over flat idlers at suitable pitch and 20 in. dia. terminal drums. The general construction of the framework and mode of driving would be similar to previous conveyers, except that trestles and walking gangway would be provided along the entire length of the conveyer. A 3 h.p. motor would be required to drive this unit.	£360
Item 16. ONE MILD STEEL OVERHEAD STRUCTURE. This structure would consist of suitable channel and angle sections, complete with $\frac{1}{4}$ in. chequer plate gangway, to support the distributing belt and overhead hoppers to the moulding machine.	£415
Item 17. TWELVE MILD STEEL STORAGE HOPPERS. These hoppers would be of tapered conical sections built up from $\frac{1}{4}$ in. plate and welded to give a smooth surface inside. Cast-iron gate valves would be fitted at the bottom to regulate the flow of sand.	£395
Item 18. ONE 16 in. BELT CONVEYER, 215 ft. centres. This conveyer would be of similar construction to Item 15, but twelve sets of adjustable ploughs would be provided over the storage hoppers (Item 17). A 5 h.p. motor would be required to drive this unit.	£575
Item 19. 3 ton SAND STORAGE HOPPER. This hopper would be generally similar in construction to Item 7, except that a cast-iron gate valve would be fitted at the mouth.	£60
Item 20. TWELVE 24 in. GRAVITY ROLLER CONVEYERS, each 55 ft. long. These conveyers are for	

returning the empty boxes to the moulding machine, and lie at an incline. The rollers would be 2¼ in. dia. at 5 in. pitch and specially constructed to be dust-proof. All rollers would run on ball bearings with fixed spindles. It will be noticed that the 5 in. pitch we have quoted will not be suitable for 10 in. × 9 in. and 7 in. × 7 in. moulding boxes, but as the quantity to be used is very small we would suggest that these boxes are placed on plates when they are on the conveyer, otherwise the cost of gravity run to take this size of box would be considerably increased. We have put forward the special type of dust-proof rollers as we consider they are the best type for foundry work. On the other hand we could supply our standard type of ball bearing rollers, which are not dust-proof, at a considerably lower price, but we are sure that trouble would be experienced by the rollers wearing out very quickly. *Price* £1250

Item 21. Six 24 in. Gravity Roller Tables, 55 ft. long. These tables would be exactly similar to Item 20, except that they would be horizontal. £680

General

All drives would be guarded in sheet steel cases.

All bearings would be of the ball bearing type and would be dust-proof.

All materials would be of British manufacture and workmanship and would be the best of their respective kinds.

All belts would be of 28 in. duck quality with a cover, ultimate tensile strength of 4000 lb., and where necessary would be of heat-resisting rubber, guaranteed up to 300° F.

We would supply all necessary holding-down bolts and would give all steelwork one coat of paint before leaving our Works and another coat after erection.

Our tender includes for the covering of pits, but does not include for any curb angles or fixings to concrete.

The plant would be erected on prepared foundations, and we do not include for any cutting away and making good of floors, walls, etc.

Conditions of Sale

A fundamental aspect of price-fixing is that of the conditions of sale. Unless these are clearly defined beforehand, it becomes virtually impossible to include in the selling price any intelligent provision for contingencies. The following is, therefore, suggested as a basis—

CONDITIONS OF SALE

1. *Written Order*

No order shall be binding until its acceptance has been confirmed in writing.

2. *Time of Delivery*

The time of delivery shall be reckoned from the date of receipt of the order or of the necessary information and drawings, whichever date may be the later; no liability for failure to deliver within the time given shall arise unless by virtue of a specific undertaking under an agreed penalty as liquidated damages.

3. *Dispute*

In the event of a dispute, it shall be referred to an arbitrator.

4. *Guarantee*

We will only be responsible for the capacity and performance of the goods supplied being sufficient and/or suitable for your purpose provided you shall have given us full and accurate particulars of your requirements in this respect and of the conditions under which the same will be required to operate.

Whilst we will use our best endeavours with regard to the design, quality of material and workmanship of the goods supplied, we give no guarantee or warranty in respect thereof, nor shall any such be implied, but in lieu thereof we undertake to replace or repair at our option and to deliver carriage paid within   or within the Railway Companies' free delivery area, any goods or parts thereof proved to have been originally defective in design, material, or workmanship, if promptly returned to our works, carriage paid, within   months from the date of dispatch.

5. *Clerical Errors*

All clerical and stenographical errors and omissions shall be subject to subsequent

correction, and orders based upon quoted prices are not binding until our acceptance has been notified. We expressly reserve the right to increase prices quoted by such additional sum or sums as may be necessary to cover any increase in rates of wages, enhanced cost of materials, or other cause or factor beyond our control.

6. *Inspection*

All goods offered are of our standard types and quality, unless specially agreed otherwise. Inspection at our Works is invited, as we accept no responsibility for any loss arising through any misunderstanding, damage or expense incurred either before or subsequent to dispatch, and we will not be responsible for any alteration or work performed on material furnished by us, unless we have given authority for same in writing.

7. *Quotations*

Quotations covering fixing or erection of materials are based on the work being executed during ordinary working hours, and overtime will be charged extra. We do not guarantee the skill or ability of our employees, but we will do our best to supply suitable and reliable workers strictly on condition, however, that we are kept indemnified by the hirer against all loss or damage incurred during the hiring, or arising out of any work on which our employees may have been engaged. Time spent in starting the machinery, or attending same after starting, will be charged for unless agreed otherwise. After delivery on site buyers accept responsibility for any loss or damage occasioned by fire or accident to premises to which all or any portion of the materials covered by contract may be subject. Our offers do not include either excavators', masons', bricklayers', or carpenters' work or materials, and unless otherwise stated all quotations and charges are net.

8. *Date of Delivery*

Contracts as to date of delivery are conditional upon disputes with workmen, accidents to works, machinery, or other causes beyond our control, and we take no responsibility for any loss due to delays or accidents in transit. All contracts shall be interpreted in all respects in accordance with the laws of Great Britain.

9. *Cancellation of Orders*

Orders cannot be countermanded except with our consent, and on terms which will indemnify us against all loss. Orders per telephone or telegrams are executed at buyer's risk.

10. *Return of Goods*

Goods returned without our consent will not be accepted for credit.

11. *Storage*

Should buyers be unable to take over goods when same are ready for delivery, it is understood that we have the right to invoice for payment just as if our part of the contract had been fulfilled. Storage charges will be made for goods remaining on our hands longer than one month, and interest at the rate of 5 per cent per annum will be charged to the purchaser on overdue accounts. We claim a lien upon all materials, plant or machinery, whether erected or not, for any unpaid balance due to us, and any instalment of purchase money which may have been paid shall be retained by us for our own use.

12. *Delivery*

Delivery is made at our Works. If to meet customer's requirements we pay carriage, the goods will be forwarded at buyer's risk and carriers will act as buyer's agents in handling same. Before giving carriers a receipt the goods tendered should be carefully examined, and refused if damaged. When this cannot be done please sign for the materials as unexamined. The carriers must be advised of any irregularity within three days of receipt, otherwise claims cannot be enforced.

Effectiveness of Salesmen

Salesmen can be the strong or the weak link in a firm's sales chain. The effectiveness of a salesman is dependent upon many factors, of which his personality and pertinacity, important as they are, are by no means the sum total. An engineering salesman, to make any marked impression, must be technically competent to talk on even terms with his prospective customer, and, in addition, able to act as a specialist authority in regard to the product he is trying to sell.

What the salesman says and does as he faces his prospects and customers is vitally important to the success of the business, and his success depends, to a great extent, upon the words he uses in the field of selling. The most superior products will not sell themselves. There is need for the intelligent persuasion of a salesman's words, backed up by sound selling technique. His initial training must, therefore, be "broadmindedly technical," for his specialist knowledge must have a wide basis if he is to be able to interpret aright the information, often vague, that reaches him bearing on the requirements of the prospective buyer and the trend of competition. He must go to his interviews with really adequate technical information as well as full instruction regarding his firm's policy in regard to competition, design, price, credit, and delivery, etc. His bearing must have the confidence that comes from a complete understanding with his own head office and from experience of the firm's efficiency in general. Not every man with this sort of training and support can become an effective salesman, but no salesman will be likely to make maximun use of his opportunities and make his own contribution to the firm's prestige unless these conditions exist.

Reasons for Failure

There are at least three very common reasons why so many salesmen fail. (1) They have the wrong temperament and the wrong type of brain for selling. They are not by nature friendly and adaptable and able to get on with other people. A man who would be a success as a works manager or accountant or chemist may be a total failure as a salesman. Salesmanship requires a certain type of mind and temperament. (2) They have not learned the right way to sell. They have the self-conceit to think that they do not need to learn from others. There are many such salesmen, but they never rise into the first rank. (3) They do not work hard. They are trusted to make good use of their time but instead they start the day late, take an unduly long time over lunch, and end the day as soon as possible. Many salesmen lose at least half an hour a day in one or another of these ways, little realizing what this loss means. It represents about nineteen eight-hour days a year more time than most people spend on holidays. It means nearly 7 per cent of the working time, and a 7 per cent loss is a heavy one. If a salesman is being paid £1000 a year and he loses half an hour a day, the value of his lost time in a year is about £62. This is enough to pay the interest, at 5 per cent, on £1240. It will be seen, therefore, that it is no small matter to lose half an hour a day. It is indeed a moral defect which holds back many a competent man and is difficult to eradicate.

The first type should move to some congenial sort of work, the second should learn the art of salesmanship, and the third should have a moral awakening, take themselves in hand and make themselves worthy of the confidence of their firms. The misplaced, the untrained, and the slackers,

can never excel in the difficult business of selling.

A salesman requires three kinds of knowledge--

(1) Knowledge of the goods.

(2) Knowledge of customers.

(3) Knowledge of salesmanship.

No salesman can sell wireless sets one month and motor cars the next. A few salesmen have the delusion that they can do this. They try it and fail. They do not half learn how to do their jobs. To know the goods is not enough. A man who is competent in the factory may be a failure on the road.

Technical men are frequently inclined to undervalue the art of salesmanship. They do not learn how to handle customers and how to sell, and that is the reason for their frequent failure when sent out as salesmen.

Selection and Training of Salesmen

It is advisable to draw up a schedule of points for investigating a salesman's job. Such a survey should include the following preliminaries -

1. *Outside Factors*

(*a*) Does salesman have a car or work on foot?

(*b*) How much equipment does he carry?

(*c*) What class of customer is in his territory?

2. *Routine Duties*

(*a*) How much of the salesman's time is spent in keeping the car clean and in good repair?

(*b*) Does he have any difficulty in protecting stock and equipment?

(*c*) How much time is required for daily report? When does he prepare it?

(*d*) How does he handle invoices and collections?

(*e*) What time is spent in correspondence and credit reports?

3. *Salesman's Methods of Working*

(*a*) Does he sell or merely take orders?

(*b*) Does he understand the firm's sales policy?

(*c*) Does he take advantage of his full line to build up an assorted order, or does he sell only one class of article to each customer?

(*d*) Does he secure customers' interest and goodwill?

4. *Salesman's Attitude Towards his Job*

(*a*) Does he like his job?

(*b*) What parts of the job does he like least?

(*c*) Does he consider the report system burdensome?

(*d*) Is he acquainting himself with his territory and its sales possibilities?

(*e*) Does he introduce local sales arguments?

(*f*) Does he study individual customers to learn how to handle them?

(*g*) Is he studying his methods of selling and improving his sales talk? Does he try out new ideas?

(*h*) Does he want or expect promotion? Is he preparing himself to merit it?

5. *Supervision*

(*a*) How often does the sales or branch manager visit the salesman on his territory?

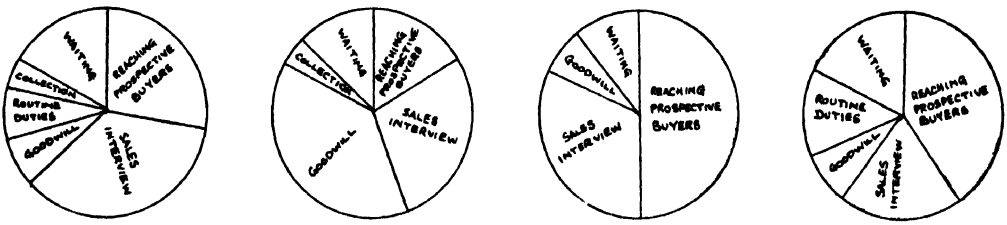
(*b*) What help does his superior give him?

(*c*) What does the salesman think his superior ought to do for him?

(*d*) Are the sales letters and bulletins from the sales office helpful? How does he make use of them?

approximate time study of a salesman's activities, and graphical representation of these activities will often reveal much useful information.

Fig. 335 broadly represents what takes place in the case of four salesmen operating in different areas. This type of analysis will form a basis for still further investigation.



No. 1 No 2 No 3 No 4

FIG. 335. GRAPHICAL REPRESENTATION OF SALESMEN'S DUTIES

6. *Attitude Towards the Firm*

(*a*) Does the salesman like the firm? Does he get fair treatment?

(*b*) Does he like the firm's sales policies and plans? What criticism, if any, does he make?

(*c*) Does he think the commission plan works out well? Is he satisfied with his own income?

(*d*) Does the firm recognize merit? Does the salesman think he has a chance to rise in the organization?

7. *Incentives*

(*a*) How are territories allotted?

(*b*) How are quotas set?

(*c*) What incentives are offered for beating quotas?

(*d*) What kinds of contests are conducted? How often?

(*e*) To what extent is recognition given in the "house organ" (i.e. a weekly, monthly or quarterly bulletin or periodical, issued by the firm)?

It is generally possible to effect an

Sales Department Statistics

A sales department must register all contracts obtained, and issue the requisite office orders to all departments concerned. Another functional aspect, allied to registration and linked up with the work of estimating, accounting, costing and other recording departments, is that of comparison. It involves the collation and comparison of statistics and non-technical data, from within and without the sales department, for the sales manager himself, to guide his instructions to those under his authority, especially salesmen and agents, and to support his recommendations to the higher management. Certain major statistics, such as orders received, sales, turnover and orders outstanding, should, as mentioned in Chapter I, be represented by graphs—the most

constructive use to which any statistics can be put—in order to disclose trends. The Gantt chart, for instance (see Chapter XXIII), serves a particularly useful purpose when applied to sales, and it is suggested that comparisons be made by plotting separately the orders obtained in each of the following areas—

South. West. Midlands North East North

The line of demarcation of each area is best defined on a large scale map.

The last sales department function is that of investigation. This may include investigation necessary to interpret an inquiry in terms of a definite specification, on which a tender may be based. It may also cover the investigation of complaints and suggestions from customers, salesmen and agents, including the apparent causes of lost orders. Competent initiative in this sphere should serve as a means of co-ordinating the work of the research and development department with everyday sales experience. The dividing line between investigation and development is that investigation should report to the research and development department the relevant evidence collected, leaving to the latter the task of finding the solution to the problem. There is, of course, the reverse process of discovering the market possibilities of products sponsored by the research and development department.

Market Study

The study of markets is the basis of the future policy of production for the firm. On its results the factory and orders are planned for the next period of production, say, one year. It consists of an intelligent survey of previous years' activities noting the fluctuation of supply and demand for various reasons. Many products are subject to seasonal fluctuation, and there are other variations, some at periods of several years, or perhaps only a month. These cycles are quite regular and it is necessary to make provision for them. Other variations are due to abnormal circumstances such as flood, war, fire, etc., but for obvious reasons these cannot be so readily predicted. Then trade conditions are extremely important and a careful study of the general market conditions before going into production is very necessary. Graphs should be plotted to show these trends separately and collectively, and from their examination it should be possible to make a fairly accurate forecast of the demand for the next production period.

The figures for previous years will be in the department's history. Figures of up-to-date conditions are obtained from the sales staff and branch managers who send in their individual estimates. With the knowledge of these fluctuations it is possible to extend the curves for the coming year, taking into account any abnormality. Having established the required production, it will be possible to smooth out the load on the factory by manufacturing for stock. It may be necessary to extend the works, utilize some by-product, or use different production methods, as a result of the season's forecast. It is clear,

therefore, that a study of the market plays a large part in the future policy of any individual concern. There may also be cyclic and trend variations in raw materials, and a close watch should be kept on these with a view to economical purchase.

Market Study in Relation to Technical Development

Technical development tends to set up a competition which, in obtaining a market for a new product, may do so at the expense of the market for an existing product, at least for a time. So irresistible is the advance of technical development that no manufacturer can afford to be complacent To eliminate the need of everyone keeping incessant watch for himself, research associations have, as mentioned in Chapter XXV, become operative for most industries. The information which these associations may disseminate to their members has the effect of throwing on to the shoulders of the individual manufacturer the onus of applying the information to the particular circumstances of his business, hence the genesis of the research and development department to work out the problems induced by economic and technical competition. Technical competition may have to be met by economic measures, e.g. reducing unit cost by larger production; and economic competition by technical measures, e.g. increasing the efficiency of the product.

With technical products, market research calls for the consideration of economic and technical factors concurrently, and all substantial proposals arising from such study, after being properly formulated and confidentially circulated, require to be discussed adequately at a staff conference. A source of guidance in development work may be the reports on after-sales service.

Technical Service

There is no doubt that when a product has been sold, it is in the manufacturer's own interest that the customer shall obtain the best results possible from its use. To what extent actual technical service is necessary for this purpose depends on the type of product and the degree to which any particular design has been made fool-proof. In any event, there may be possibilities of actively rendering assistance and keeping the customer's goodwill. The normal channel of communication is the salesman or agent, or perhaps the "house organ." Circular letters may be used sometimes as an alternative. Broadly speaking, the initiative regarding after-sales service should be centred in the research and development department. It tends to give realism to their work if the staff remain in the closest contact with the performance of products in service, and do not allow themselves to be interested only in new projects. This practice should steady the release of new designs before they have been sufficiently proved under service conditions.

Working Instructions

The drawing up of working instructions is a basic phase of after-sales

service, and the research and development department should undoubtedly be responsible for this important work.

Guidance is necessary for what may be called standardized repairs, and indication should be given as to the points where wear is likely to occur and the steps to be taken to overcome it. For many engineering products an all-important form of after-sales service is to facilitate the supply of spare parts. In this connection, a cable code may be regarded as a very valuable factor. At the same time, by close scrutiny of the demand for spare parts, particularly having regard to the total number of such parts estimated to be in use, evidence of faulty operation or faulty design may be established. Where this occurs, steps should be taken by the design and associated departments to obviate recurrence in the future.

APPENDIX

Weights and Measures

BRITISH WEIGHTS AND MEASURES

LINEAL MEASURE

4 Inches	1 Hand.	5½ Yards	1 Rod, Pole, or Perch.
9 ,,	1 Span.	4 Poles	1 Chain.
12 ,,	1 Foot.	10 Chains	1 Furlong.
3 Feet	1 Yard.	8 Furlongs	1 Mile.
5 Feet	1 Pace.	3 Miles	1 League.
6 Feet	1 Fathom.	1·151 Miles	1 Nautical Mile.

1 Link	7·92 Inches.	
1 Chain	100 Links	22 Yards.
80 Chains	1 Mile	1760 Yards.

A Knot is a speed of 1 Nautical Mile per hour.

CUBIC OR SOLID MEASURE

Cubic Foot	1728 Cubic Inches	
Cubic Yard	27 Cubic Feet	21·033 bushels.
Stack of Wood	108 Cubic Feet.	
Shipping Ton	40 Cubic Feet merchandise.	
Shipping Ton	42 Cubic Feet of timber.	
Ton of displacement of a ship	35 Cubic Feet.	

SQUARE OR LAND MEASURE

144 Square Inches	1 Square Foot.
9 Square Feet	1 Square Yard.
30¼ Square Yards	1 Square Perch.
40 Perches	1 Rood.
4 Roods	1 Acre.
640 Acres	1 Square Mile.
An Acre	= 4840 Square Yards.
1 Square Link	62¾ Square Inches (approx.)
1 Square Chain	10,000 Square Links 484 Sq. Yards.
10 Square Chains	1 Acre — 100,000 Sq. Links = 4840 Sq. Yards.
36 Square Yards	1 Rod of Building.
100 Square Feet	1 Square of Flooring.
272¼ Square Feet	1 Rod of Bricklayer's Work.

HYDRAULIC MEMORANDA

1 Gallon of Water	10 lb.
1 Cubic Foot of Water	6¼ Gall. (approx.).
	62½ Lb.
1 Inch of Rainfall	22,622 Gallons per Acre.
	100 Tons (approx.).

1 Gallon of Milk weighs approximately 10⅓ lb.

APOTHECARIES' WEIGHT

20 Grains	1 Scruple, ℈.
3 Scruples (60 gr.)	1 Drachm, ʒ.
8 Drachms (480 gr.)	1 Ounce, ℥.
12 Ounces (5760 gr.)	1 Pound, ℔.

Drugs are compounded by this weight.

TROY WEIGHT

3·17 Grains =	1 Carat.	20 Dwts. =	1 Ounce.
24 ,, =	1 Dwt.	12 Ounces =	1 Pound.

1 pound troy = 5760 grains. 1 oz. troy = 5760/12 = 480 grains.
The standard for gold coin is 22 carats fine gold and 2 carats alloy.

AVOIRDUPOIS WEIGHT

16 Drams	1 Ounce (437·5 gr.*).
7000 gr. (16 Ounces)	1 Pound (lb.).
14 Pounds	1 Stone.†
28 Pounds	1 Quarter.
112 Pounds	1 Hundredweight (cwt.).
2240 lb. or 20 cwt. =	1 Ton.

* A grain is the same in all weights. † Butcher's Stone is 8 lb.

MEASURES OF CAPACITY—DRY MEASURE

1 Minim =	1 Drop.	2 Gallons =	1 Peck.
1 Dram	1 Teaspoon.	4 Pecks =	1 Bushel.
2 Drams	1 Dessertspoon.	(8 Galls.)	(1·2837 cub. ft.).
4 Drams	1 Tablespoon.	2 Bushels =	1 Strike.
60 Minims	1 Drachm, fʒ.	3 Bushels	1 Sack.
8 Drachms =	1 Ounce, f℥.	4 Bushels =	1 Coomb.
20 Ounces =	1 Pint.	8 Bushels =	1 Quarter.
4 Gills* =	1 Pint.	12 Sacks	1 Chaldron.
2 Pints =	1 Quart.	5 Quarters =	1 Wey or Load.
2 Quarts =	1 Pottle.	10 Quarters =	1 Last.
4 Quarts =	1 Gallon.		

An Imperial Gallon of distilled water weighs 10 lb. avoirdupois.
A wineglass holds about 2 oz.; a teacup about 3 oz.
* In the North of England half a pint is called a gill, and a true gill a "noggin."
The average weight of a bushel of barley is 47 lb., oats 38 lb., wheat 60 lb.

WINE AND SPIRIT MEASURE

4 Gills	1 Pint.	63 Gallons	1 Hogshead.
2 Pints	1 Quart.	84 Gallons =	1 Puncheon.
4 Quarts	1 Gallon.	2 Hogsheads =	1 Pipe.
31½ Gallons	½ Hogshead.	2 Pipes	1 Tun.

U.S.A.	(Mile)	1760 yds.	(Ton)	2000 lb.
France	(K.metre)	1094 ,,		
Germany	(,,)	1094 ,,	1 Kilogramme = 1000 grammes 2·205 lb.	U.S.A.— Imperial Liquid Measure
Italy	(Chilometro)	1094 ,,		
Portugal	(Kilometre)	1094 ,,		
Spain	(Kilometro)	1094 ,,		
Switzerland	(Lien)	5249 ,,		
Turkey	(Berri)	1828 ,,	(Oke)	2·8342 lb.
Netherlands	(Kilometre)	1094 ,,	(Oncen)	·22 lb.
Denmark	(Mil)	8238 ,,	(Alen) or Kg.	
Russia	(Verst)	1167 ,,	(Pood)	36·11 lb.

Metric and Decimal Equivalents of Fractions of an Inch

Fractions Inches				mm.	Decimals Inches	Fractions Inches				mm.	Decimals Inches
			$\frac{1}{64}$	0·396	·015625				$\frac{33}{64}$	13·096	·515625
		$\frac{1}{32}$		0·793	·03125			$\frac{17}{32}$		13·492	·53125
			$\frac{3}{64}$	1·190	·046875				$\frac{35}{64}$	13·890	·546875
	$\frac{1}{16}$			1·587	·0625		$\frac{9}{16}$			14 287	·5625
			$\frac{5}{64}$	1·984	·078125				$\frac{37}{64}$	14·683	·578125
		$\frac{3}{32}$		2·381	·09375			$\frac{19}{32}$		15·080	·59375
			$\frac{7}{64}$	2·778	·109375				$\frac{39}{64}$	15·477	·609375
$\frac{1}{8}$				3·175	·125	$\frac{5}{8}$				15 875	·625
			$\frac{9}{64}$	3·571	·140625				$\frac{41}{64}$	16·271	·640625
		$\frac{5}{32}$		3·968	·15625			$\frac{21}{32}$		16·667	·65625
			$\frac{11}{64}$	4·365	·171875				$\frac{43}{64}$	17·064	·671875
	$\frac{3}{16}$			4·762	·1875		$\frac{11}{16}$			17·462	·6875
			$\frac{13}{64}$	5·159	·203125				$\frac{45}{64}$	17·858	·703125
		$\frac{7}{32}$		5·556	·21875			$\frac{23}{32}$		18·255	·71875
			$\frac{15}{64}$	5 952	234375				$\frac{47}{64}$	18·652	·734375
$\frac{1}{4}$				6 350	·25	$\frac{3}{4}$				19·050	·75
			$\frac{17}{64}$	6·746	·265625				$\frac{49}{64}$	19·446	·765625
		$\frac{9}{32}$		7·143	·28125			$\frac{25}{32}$		19 842	·78125
			$\frac{19}{64}$	7·540	·296875				$\frac{51}{64}$	20·239	·796875
	$\frac{5}{16}$			7·937	·3125		$\frac{13}{16}$			20·637	·8125
			$\frac{21}{64}$	8·334	·328125				$\frac{53}{64}$	21·033	828125
		$\frac{11}{32}$		8·730	·34375			$\frac{27}{32}$		21·429	·84375
			$\frac{23}{64}$	9·127	·359375				$\frac{55}{64}$	21·827	·859375
$\frac{3}{8}$				9·525	·375	$\frac{7}{8}$				22·225	·875
			$\frac{25}{64}$	9 921	·390625				$\frac{57}{64}$	22·621	·890625
		$\frac{13}{32}$		10·318	·40625			$\frac{29}{32}$		23·017	·90625
			$\frac{27}{64}$	10 715	·421875				$\frac{59}{64}$	23·414	·921875
	$\frac{7}{16}$			11·112	·4375		$\frac{15}{16}$			23·812	·9375
			$\frac{29}{64}$	11 508	·453125				$\frac{61}{64}$	24·208	·953125
		$\frac{15}{32}$		11·905	·46875			$\frac{31}{32}$		24·604	·96875
			$\frac{31}{64}$	12·302	·484375				$\frac{63}{64}$	25·002	·984375
$\frac{1}{2}$				12·700	·5	1				25·399	1·0

Metric Equivalents of Feet and Inches

	0	1	2	3	4	5	6	7	8	9	10	11	12	Feet
Ins. 0	·0	·305	·610	·914	1 219	1·524	1 829	2·133	2·438	2 743	3·048	3·352	3·657	Metres
1	·0254	·330	·635	·940	1·244	1·549	1·854	2·158	2 463	2·768	3 073	3·378	3·682	,,
2	·0508	·356	·660	·965	1·269	1·575	1·880	2·184	2·489	2·794	3·099	3·403	3·708	,,
3	·0762	·381	·686	·991	1·295	1·600	1·905	2·209	2·514	2·819	3 124	3·429	3·733	,,
4	·1016	·406	·711	1·016	1·320	1·626	1·931	2·235	2·540	2·844	3·150	3·454	3·759	,,
5	·1270	·432	·737	1·041	1·346	1·651	1·956	2·260	2·565	2·870	3·175	3·479	3·784	,,
6	·1524	·457	·762	1·066	1·371	1·676	1 981	2·286	2·590	2·895	3·200	3·505	3·810	,,
7	·1778	·483	·787	1·092	1·397	1·702	2·007	2·311	2·616	2·921	3·226	3·530	3·835	,,
8	·2032	·508	·813	1·117	1·422	1·727	2 032	2·336	2·641	2 946	3·251	3·555	3·860	,,
9	·2286	·533	·838	1·142	1·448	1·753	2·057	2·362	2·667	2 972	3·276	3·581	3·886	,,
10	·2540	·559	·864	1·168	1·473	1·778	2·083	2·387	2·692	2·997	3·302	3·606	3·911	,,
11	·2794	·584	·889	1·193	1·498	1 803	2·108	2·412	2·717	3 022	3·327	3·632	3·936	,,

Cm. and Mm. to Inches

	0	1	2	3	4	5	6	7	8	9	10 Cms.
Mm. 0	0	·3937	·7874	1·1811	1·5748	1·9685	2 3622	2·7559	3·1496	3·5433	3·9370 In.
,, 1	·0394	·4331	·8268	1·2205	1 6142	2·0079	2·4016	2·7953	3·1890	3·5827	,,
,, 2	·0787	·4724	·8661	1·2598	1·6536	2·0473	2·4410	2·8347	3·2284	3·6221	,,
,, 3	·1181	·5118	·9055	1·2992	1·6929	2·0866	2·4803	2·8740	3·2677	3·6614	,,
,, 4	·1575	·5512	·9449	1·3386	1 7323	2·1260	2·5197	2·9134	3 3071	3·7008	,,
,, 5	·1968	·5906	·9843	1·3780	1·7717	2 1654	2·5591	2·9528	3·3465	3·7402	,,
,, 6	·2362	·6299	1·0236	1·4173	1·8110	2·2047	2·5984	2·9922	3·3859	3·7796	,,
,, 7	·2756	·6693	1·0630	1·4567	1·8504	2·2441	2·6378	3·0315	3·4252	3·8189	,,
,, 8	·3150	·7087	1·1024	1·4961	1·8898	2·2835	2·6772	3·0709	3·4646	3·8583	,,
,, 9	·3543	·7480	1·1417	1·5354	1 9291	2 3228	2·7166	3·1103	3 5040	3·8977	,,

Decimetres and Cm. to Inches

	0	1	2	3	4	5	6	7	8	9	10 Decimetres
Cm. 0	0	3 9370	7 8741	11·8111	15 7482	19·6852	23·622	27·559	31·496	35·433	39 370 In.
,, 1	·3937	4·3307	8·2678	12·2048	16·1419	20·079	24·016	27·953	31 890	35·827	,,
,, 2	·7874	4·7245	8·6615	12·5985	16·5356	20·473	24·410	28·347	32·284	36·221	,,
,, 3	1·1811	5·1182	9·0552	12·9922	16 9293	20·866	24 803	28·740	32·677	36·614	,,
,, 4	1·5748	5 5119	9·4489	13·3859	17·3230	21·260	25·197	29·134	33·071	37·008	,,
,, 5	1·9685	5·9056	9·8426	13 7796	17·7167	21·654	25·591	29·528	33 465	37·402	,,
,, 6	2·3622	6·2993	10·2363	14·1734	18 1104	22·047	25·984	29·922	33 859	37·796	,,
,, 7	2·7559	6·6930	10·6300	14·5670	18 5041	22·441	26·378	30·315	34·252	38·189	,,
,, 8	3·1496	7 0867	11·0237	14·9608	18·8978	22·835	26·772	30·709	34·646	38·583	,,
,, 9	3·5433	7·4804	11·4174	15·3545	19·2915	23·228	27·166	31·103	35·040	38·977	,,

Kilos. per Sq. Mm. to Tons per Sq. Inch

	0	1	2	3	4	5	6	7	8	9	10 Kilos/sq. mm
20	12 700	13 335	13 970	14 605	15·240	15 875	16 510	17·145	17 780	18·415	6·350 Tons per Sq. in.
30	19·050	19·685	20·320	20·955	21·590	22·225	22·860	23·495	23 130	24·765	
40	25 400	26·035	26·670	27·305	27·940	28·575	29 210	29·845	30 480	31·115	
50	31·750	32·385	33·020	33·655	34·290	34·925	35·560	36·195	36·830	37·465	
60	38·100	38·735	39·370	40 005	40·640	41·275	41·910	42·545	43·180	43·815	
70	44·450	45 085	45·720	46·355	46 990	47·625	48·260	48·895	49·530	50·165	
80	50 800	51·435	52 070	52·705	53 340	53 975	54 610	55·245	55 880	56·515	
90	57·150	57·785	58·420	59 055	59 690	60·325	60 960	61·595	62 230	62 865	

By means of above table the value in inches of any number of millimetres up to 1000 may be obtained, e.g. the value of ·861 metre is found as follows—

·861 metre = 8 decimetres + 6 cms. + 1 mm.
= 31·496 + 2·3622 + ·0394 in.
= 33·898 in. (to 3 decimal places).

Or: From 2nd table, 8 dm. = 31·496 in.
,, 1st ,, 61 mm. = 2·4016 in.

∴ ·861 in. = 33·898 in.

GENERAL CONVERSION TABLE

Multiply by	*To convert*	*To*	
2·54	Inches	Centimetres	·3937
30·48	Feet	,,	·0328
·914	Yards	Metres	1·094
1,609·3	Miles	,,	·000621
1,853·27	Nautical Miles	,,	·000539
6·45	Square inches	Sq. cm.	·155
·093	Square feet	Sq. Metres	10·764
·836	Square yards	,,	1·196
16·39	Cubic inches	Cub. cms.	·061
28·3	Cubic feet	Litres	·0353
6·24	,, ,,	Gallons	·1602
·765	Cubic yards	Cub. Metres	1·308
·3372	Pounds (Troy)	Kilogrammes	2·68
31·10	Ounces (Troy)	Grammes	·03216
·4536	Pounds (Avoir.)	Kilogrammes	2·2045
7,000	,, ,,	Grains (Troy)	·000143
28·35	Ounces (Avoir.)	Grammes	·0352
·065	Grains	,,	15·38
50·8	Cwt.	Kilogrammes	·01968
1,016·0	Tons	,,	·000984
4·546	Gallons	Litres	·22
10	Gallons of water	Pounds	·1
·454	Pounds of water	Litres	·2202
70·3	Lb. per sq. in.	Gm./sq. cm.	·0142
2·3	,, ,,	Head of water (ft.)	·434
0·7	,, ,,	,, ,, (M.)	1·4285
·068	,, ,,	Atmospheres	14·7
1·575	Tons per sq. in.	Kgm./sq. mm.	·635
4·883	Lb. per sq. ft.	Kgm./sq. metre	·205
·593	Lb. per cub. yd.	Kgm./cub. metre	1·686
16·02	Lb. per cub. ft.	,, ,,	·0624
·0998	Lb. per gallon	Kgm./litre	10·02
·138	Foot-lb.	Kilogrammetres	7·23
·33	Foot-tons	Tonne-metres	3
1·014	Horse-power	Force de cheval	·9861
746	,,	Watts	·00134
33,000	,,	Ft.-lb./min.	——
76	,,	Kg.-m./sec.	·01316
44	Watts	Ft.-lb./min.	·0227
0·1	,,	Kg.-m./sec.	10
0·252	Heat units	Calories	3·97
14·7	Atmospheres	Lb./sq. inch	·068
0·90	German candles	English candles	1·1111
9·55	Carcels	Candles	·1047
·737	Joules	Ft.-lb.	1·357
88	Miles/hour	Ft./min.	·01134
197	Metres/sec.	,,	·00508
1·8	C.H.U.	B.Th.U.	·5555
0·0208	Centipoise	Lb./in.^{2} sec.	48
	To obtain	*From*	*Multiply by above*

SPEED TABLE

Time per mile (secs.)	Miles/hour	Km./hour	Time per mile (secs.)	Miles/hour	Km./hour
15	240·0	386·2	36	100·0	160·9
16	225·0	362·1	38	94·7	152·4
17	211·8	340·8	40	90·0	144·8
18	200·0	321·8	45	80·0	128·7
19	189·5	305·0	50	72·0	115·9
20	180·0	289·7	55	65·5	105·4
21	171·4	275·8	60	60·0	96·6
22	163·6	263·3	65	55·4	89·2
23	156·5	251·9	70	51·4	82·7
24	150·0	241·4	75	48·0	77·2
25	144·0	231·7	80	45·0	72·4
26	138·5	222·9	85	42·4	68·2
27	133·3	214·5	90	40·0	64·4
28	128·6	207·0	95	37·9	61·0
29	124·1	199·7	100	36·0	57·9
30	120·0	193·1	110	32·7	52·7
31	116·1	186·8	120	30·0	48·3
32	112·5	181·0	140	25·7	41·4
33	109·1	175·6	160	22·5	36·2
34	105·9	170·4	180	20·0	32·2

Time per km. (secs.)	Km./hour	Miles/hour	Time per km. (secs.)	Km./hour	Miles/hour
10	360·0	223·7	30	120·0	74·6
11	336·4	209·0	32	112·5	69·9
12	300·0	186·4	34	105·9	65·8
13	276·9	172·1	36	100·0	62·2
14	257·2	159·8	38	94·7	58·9
15	240·0	149·1	40	90·0	55·9
16	225·0	139·8	45	80·0	49·7
17	211·8	131·6	50	72·0	44·8
18	200·0	124·3	55	65·5	40·7
19	189·5	117·8	60	60·0	37·3
20	180·0	111·8	65	55·4	34·4
21	171·4	106·5	70	51·4	31·9
22	163·6	101·7	80	45·0	27·9
23	156·5	97·2	90	40·0	24·8
24	150·0	93·2	100	36·0	22·4
25	144·0	89·5	110	32·7	20·3
26	138·5	86·1	120	30·0	18·6
27	133·3	82·8	140	25·7	15·9
28	128·6	79·9	160	22·5	14·0
29	124·1	77·1	180	20·0	12·4

1·6093 km. = 1 mile. ·6214 mile = 1 km.

$$\text{Miles/hour} = \frac{3600}{\text{secs./mile.}} \qquad \text{Km./hour} = \frac{3600}{\text{secs./km.}}$$

$$\text{Miles/hour} = \frac{2237}{\text{secs./km.}} \qquad \text{Km./hour} = \frac{5793{\cdot}5}{\text{secs./mile.}}$$

AREAS AND CIRCUMFERENCES OF CIRCLES IN INCHES

Dia. in In.	Areas 0 in.	Areas ¼ in.	Areas ½ in.	Areas ¾ in.	Dia. in In.	Circumference 0 in.	Circumference ¼ in.	Circumference ½ in.	Circumference ¾ in.
0	·0	·0490	·1963	·4417	0	·0	·7854	1·570	2·356
1	·7854	1·227	1·767	2·405	1	3·141	3·927	4·712	5·498
2	3·141	3·976	4·908	5·939	2	6·283	7·068	7·854	8·639
3	7·068	8·295	9·621	11·04	3	9·424	10·21	10·99	11·78
4	12·56	14·18	15·90	17·72	4	12·56	13·35	14·13	14·92
5	19·63	21·64	23·76	25·96	5	15·70	16·49	17·27	18·06
6	28·27	30·68	33·18	35·78	6	18·84	19·63	20·42	21·20
7	38·48	41·28	44·18	47·17	7	21·99	22·77	23·56	24·34
8	50·26	53·45	56·74	60·13	8	25·13	25·91	26·70	27·48
9	63·61	67·20	70·88	74·66	9	28·27	29·05	29·84	30·63
10	78·54	82·51	86·59	90·76	10	31·41	32·20	32·98	33·77
11	95·03	99·40	103·8	108·4	11	34·55	35·34	36·12	36·91
12	113·1	117·8	122·7	127·6	12	37·69	38·48	39·27	40·05
13	132·7	137·8	143·1	148·4	13	40·84	41·62	42·41	43·19
14	153·0	159·4	165·1	170·8	14	43·98	44·76	45·55	46·33
15	176·7	182·6	188·6	194·8	15	47·12	47·90	48·69	49·48
16	201·0	207·3	213·8	220·3	16	50·26	51·05	51·83	52·62
17	226·9	233·7	240·5	247·4	17	53·40	54·19	54·97	55·76
18	254·4	261·5	268·8	276·1	18	56·54	57·33	58·11	58·90
19	283·5	291·0	298·6	306·3	19	59·69	60·47	61·26	62·04
20	314·1	322·0	330·0	338·1	20	62·83	63·61	64·40	65·18
21	346·3	354·6	363·0	371·5	21	65·97	66·75	67·54	68·32
22	380·1	388·8	397·6	406·4	22	69·11	69·90	70·68	71·47
23	415·4	424·5	433·7	443·0	23	72·25	73·04	73·82	74·61
24	452·3	461·8	471·4	481·1	24	75·39	76·18	76·96	77·75
25	490·8	500·7	510·7	520·7	25	78·54	79·32	80·11	80·89
26	530·9	541·1	551·5	562·0	26	81·68	82·46	83·25	84·03
27	572·5	583·2	593·9	604·8	27	84·82	85·60	86·39	87·17
28	615·7	626·8	637·9	649·1	28	87·96	88·75	89·53	90·32
29	660·5	671·9	683·3	695·1	29	91·10	91·89	92·67	93·46
30	706·8	718·6	730·6	742·6	30	94·24	95·03	95·81	96·60
31	754·8	767·0	779·3	791·7	31	97·4	98·2	98·9	99·7
32	804·2	816·9	829·6	842·4	32	100·5	101·3	102·1	102·9
33	855·3	868·3	881·4	894·6	33	103·7	104·5	105·2	106·0
34	908·0	921·3	934·8	948·4	34	106·8	107·6	108·4	109·2
35	962·1	975·9	989·8	1003·8	35	110·0	110·7	111·5	112·3
36	1017·9	1032·1	1046·4	1060·7	36	113·1	113·8	114·6	115·5
37	1075·2	1089·8	1104·5	1119·2	37	116·2	117·0	117·8	118·6
38	1134·1	1149·3	1164·2	1179·3	38	119·4	120·2	121·0	121·7
39	1194·6	1210·0	1225·4	1241·0	39	122·5	123·3	124·1	124·8
40	1256·6	1272·4	1288·3	1304·2	40	125·7	126·4	127·2	128·0

SQUARES, CUBES, SQUARE ROOTS, AND CUBE ROOTS

No.	Square	Cube	Square Root	Cube Root	No.	Square	Cube	Square Root	Cube Root
⅛	·015	·0019	·353	·5	4¼	18·062	76·765	2·061	1·61
¼	·062	·0156	·500	·629	4½	20·250	91·125	2·121	1·65
⅜	·140	·0527	·612	·721	4¾	22·562	107·171	2·179	1·68
½	·250	·1250	·707	·793	5	25	125	2·236	1·71
⅝	·390	·244	·790	·855	5¼	27·562	144·703	2·291	1·73
¾	·562	·421	·866	·908	5½	30·250	166·375	2·345	1·76
⅞	·765	·670	·935	·956	5¾	33·062	190·109	2·397	1·79
1	1	1	1·000	1	6	36	216	2·449	1·81
1⅛	1·265	1·423	1·060	1·04	6¼	39·062	244·140	2·500	1·84
1¼	1·562	1·953	1·118	1·07	6½	42·250	274·625	2·549	1·86
1⅜	1·890	2·599	1·172	1·11	6¾	45·562	307·546	2·598	1·88
1½	2·250	3·375	1·224	1·14	7	49	343	2·645	1·91
1⅝	2·610	4·291	1·274	1·17	7¼	52·562	381·078	2·692	1·93
1¾	3·062	5·359	1·322	1·20	7½	56·250	421·875	2·738	1·95
1⅞	3·515	6·591	1·369	1·23	7¾	60·062	465·484	2·783	1·97
2	4	8	1·414	1·26	8	64	512	2·828	2
2⅛	4·515	9·595	1·457	1·28	8¼	68·062	561·515	2·872	2·02
2¼	5·062	11·390	1·500	1·30	8½	72·250	614·125	2·915	2·04
2⅜	5·640	13·396	1·541	1·33	8¾	76·562	669·921	2·958	2·06
2½	6·250	15·625	1·581	1·35	9	81	729	3	2·08
2⅝	6·890	18·088	1·620	1·37	9¼	85·562	791·453	3·041	2·09
2¾	7·562	20·796	1·658	1·40	9½	90·25	857·375	3·082	2·11
2⅞	8·265	23·763	1·695	1·42	9¾	95·062	926·859	3·122	2·13
3	9	27	1·732	1·44	10	100	1000	3·162	2·15
3⅛	9·765	30·517	1·767	1·46	10¼	105·062	1076·89	3·201	2·17
3¼	10·562	34·328	1·802	1·48	10½	110·250	1157·625	3·240	2·18
3⅜	11·390	38·443	1·837	1·50	10¾	115·562	1242·296	3·278	2·20
3½	12·250	42·875	1·870	1·51	11	121	1331	3·316	2·22
3⅝	13·140	47·634	1·903	1·53	11¼	126·562	1423·828	3·354	2·24
3¾	14·062	52·734	1·936	1·55	11½	132·250	1520·875	3·391	2·25
3⅞	15·015	58·185	1·968	1·57	11¾	138·062	1622·234	3·427	2·27
4	16	64	2	1·58	12	144	1728	3·464	2·29

THERMOMETER AND HYDROMETER SCALES

The number of degrees between freezing point and boiling point of water is 212 − 32 = 180 degrees on the Fahrenheit scale, and 100 degrees on the Centigrade scale. The magnitude of the degrees F. relative to degrees C. is thus as 5 to 9.

$$\text{Temp. C.} = \tfrac{5}{9}\,(\text{F.}^\circ - 32); \quad \text{Temp. F.} = \tfrac{9}{5}\,\text{C.}^\circ + 32$$

The following formula enables degrees Baume to be converted into Specific Gravity.

$$\text{Sp. Gr.} = \frac{140}{\text{Degs. B.} + 130}; \quad \text{Degs. B.} = \frac{140}{\text{Sp. Gr.}} - 130$$

For liquids heavier than water: $\text{Sp. Gr.} = \dfrac{145}{145 - \text{Degs. B.}}$

EQUIVALENT THERMOMETER SCALES

F.°	C.°	F.°	C.°	F.°	C.°	F.	C.°
2000	1093·3	212	100·0	100	37·7	50	10·0
1900	1037·8	200	93·3	98	36·6	49	9·4
1850	1010·0	190	87·7	96	35·5	48	8·8
1800	982·2	180	82·2	94	34·4	47	8·3
1750	954·4	170	76·6	92	33·3	46	7·7
1700	926·7	160	71·1	90	32·2	45	7·2
1650	898·9	158	70·0	88	31·1	44	6·6
1600	871·1	156	68·8	86	30·0	43	6·1
1550	843·3	154	67·7	84	28·8	42	5·5
1500	815·5	152	66·6	82	27·7	41	5·0
1450	787·8	150	65·5	80	26·6	40	4·4
1400	760·0	148	64·4	78	25·5	39	3·8
1350	732·2	146	63·3	76	24·4	38	3·3
1300	704·4	144	62·2	74	23·3	37	2·7
1250	676·7	142	61·1	72	22·2	36	2·2
1200	648·9	140	60·0	70	21·1	35	1·6
1150	621·1	138	58·8	69	20·5	34	1·1
1100	593·3	136	57·7	68	20·0	33	0·5
1050	565·5	134	56·6	67	19·4	32	0·0
1000	537·8	132	55·5	66	18·8	30	1·1
900	510·0	130	54·4	65	18·3	28	2·2
950	482·2	128	53·3	64	17·7	26	3·3
850	454·4	126	52·2	63	17·2	24	4·4
800	426·7	124	51·1	62	16·6	22	5·5
750	398·9	122	50·0	61	16·1	20	6·6
700	371·1	120	48·8	60	15·5	18	7·7
650	343·3	118	47·7	59	15·0	16	8·8
600	315·6	116	46·6	58	14·4	14	10·0
550	287·8	114	45·5	57	13·8	12	11·1
500	260·0	112	44·4	56	13·3	10	12·2
450	232·2	110	43·3	55	12·7	8	13·3
400	204·4	108	42·2	54	12·2	6	14·4
350	176·7	106	41·1	53	11·6	4	15·5
300	148·9	104	40·0	52	11·1	2	16·6
250	121·1	102	38·8	51	10·5	0	17·7

EXPANSION OF BODIES BY HEAT

If l = length of bar in inches, t = temperature rise, n = coefficient of linear expansion, A = cross section of bar in inches, and E = modulus of elasticity, then increase in length of unfixed bar = ltn. If bar is fixed at both ends the temperature stress = $AtnE$.

For square surface, coefficient of expansion = 2 × linear expansion coefficient, while the coefficient of cubical expansion = 3 × linear coefficient (approx.).

In Britain the annual range of shade temperature may amount to 85° F. The maximum range from minimum winter temperature to summer sun temperature may be 135° F. In London and Glasgow the average range of shade temperature is 70°. This range is commonly allowed for in design of structures (½ in. per 100 ft.), any excess being taken by the natural elasticity of the structure. A test carried out on the Britannia Tubular Bridge showed the temperature of the material to be 120° F. in hot sunshine, and with snow on the bridge 16° F., a total range of 104° F. The allowance made for variation in length of the Forth Bridge due to change in atmospheric temperature during the year is $\frac{7}{16}$ in. per 100 ft.

COEFFICIENT OF LINEAR EXPANSION PER DEGREE FAHRENHEIT

Substance	n.	Substance	n.
Metals and Alloys		*Stone and Masonry*	
Aluminium, wrought	·0000128	Ashlar Masonry	·0000035
Brass	·0000104	Brick Masonry	·0000031
,, wire	·0000107	Cement, Portland	·0000059
Bronze	·0000101	Concrete	·0000079
Copper	·0000093	,, masonry	·0000067
German silver	·0000102	Granite	·0000047
Gold	·0000083	Limestone	·0000044
Iron, cast, grey	·0000059	Marble	·0000056
,, wrought	·0000067	Plaster	·0000092
,, wire	·0000069	Rubble masonry	·0000035
Lead	·0000159	Sandstone	·0000061
Monel	·0000076	Slate	·0000058
Nickel	·0000070		
Platinum	·0000050	*Timber*	
Platinum-Iridium, 15 per cent Ir.	·0000045	Fir } parallel to fibre	·0000021
Silver	·0000107	Maple } parallel to fibre	·0000036
Steel, cast	·0000061	Oak } parallel to fibre	·0000027
,, hard	·0000073	Pine } parallel to fibre	·0000030
,, medium	·0000067	Fir } perpendicular to fibre	·000032
,, soft	·0000061	Maple } perpendicular to fibre	·000027
Tin	·0000117	Oak } perpendicular to fibre	·000030
Zinc, rolled	·0000173	Pine } perpendicular to fibre	·000019
Miscellaneous Solids		*Liquid Substances*	*Vol. exp.*
Glass	·0000047	Alcohol	·00058
Graphite	·0000044	Acid, nitric	·00061
Gutta-percha	·0003322	,, sulphuric	·00035
Paraffin	·0001547	Mercury	·00010
Porcelain	·0000020	Oil, turpentine	·00050

WEIGHT OF METAL. LB./SQ. FT. BARS OR PLATES

	1/16	1/8	3/16	1/4	5/16	3/8	7/16	1/2	9/16	5/8	11/16	3/4	13/16	7/8	15/16	1 in.
Iron	2·5	5·0	7·5	10·0	12·5	15·0	17·5	20·0	22·5	25·0	27·5	30·0	32·5	35·0	37·5	40·0
Steel	2·55	5·10	7·65	10·20	12·75	15·30	17·85	20·40	22·95	25·50	28·05	30·60	33·15	35·70	38·25	40·80
Brass	2·78	5·50	8·33	11·10	13·88	16·65	19·43	22·20	24·98	27·75	30·53	33·30	36·08	38·85	41·63	44·40
Copper	2·86	5·72	8·58	11·44	14·30	17·16	20·02	22·88	25·73	28·59	31·45	34·31	37·17	40·03	42·89	45·75
Lead	3·71	7·42	11·13	14·84	18·55	22·27	25·98	29·69	23·40	37·11	40·82	44·53	48·24	51·95	55·66	59·38
Zinc	2·37	4·75	7·12	9·49	11·87	14·24	16·61	18·99	21·36	23·73	26·11	28·48	30·35	33·23	35·60	37·98
Monel	2·90	5·80	8·70	11·60	14·50	17·45	20·3	23·40	26·15	29·25	32·15	35·10	38·10	40·95	43·90	46·80
S.W.G.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Iron	12·00	11·36	10·36	9·52	8·80	8·12	7 20	6·60	5·92	5·36	4·80	4·36	3·80	3·32	2·88	2·60
Steel	12·24	11·59	10·57	9·71	8·98	8·28	7·34	6·73	6·04	5·47	4·90	4·44	3·88	3·39	2·94	2·65
Brass	13·32	12·61	11·50	10·59	9·77	9·01	7·99	7·33	6·57	5·95	5·32	4·84	4·22	3·68	3·20	2·89
Copper	13·73	12·99	11·85	10·89	10·07	9·29	8·24	7·55	6·77	6·13	5·49	4·99	4·35	3·80	3·29	2·97
Lead	17·81	16·86	15·38	14·13	13·06	12·05	10·69	9·80	8·79	7·96	7·13	6·47	5 64	4·93	4·28	3·86
Zinc	11·39	10·78	9·84	9·04	8·36	7·71	6·84	6·27	5·62	5·09	4·56	4·14	3·61	3·15	2·73	2·47
Monel	14·07	12·94	11·78	10·88	9·95	8·98	8·24	7·50	6·74	6·00	5·41	4·88	4·26	3·74	3·26	3·00
Aluminium	4·17	3 84	3·51	3 08	2·81	2·54	2·34	2·12	1·91	1 70	1·54	1·38	1·22	1·06	0·95	0·85
S.W.G.	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**
Iron	2·32	1·96	1·68	1·40	1·28	1·12	1·00	0·88	0·80	0·72	0·64	0·56	0·52	0·48	0·40	0·36
Steel	2·37	2·00	1·71	1·43	1·31	1·14	1·02	0·90	0·82	0·73	0·65	0·57	0·53	0·49	0·41	0·37
Brass	2·58	2·18	1·86	1·55	1·42	1·24	1·11	0·98	0·89	0·80	0·71	0·62	0·58	0·53	0·44	0·40
Copper	2·65	2·24	1·92	1·67	1·46	1·28	1·14	1·01	0·92	0·82	0·73	0·64	0·59	0·55	0·48	0·45
Lead	3·44	2·91	2·49	2·08	1·90	1·66	1·48	1·31	1·19	1·07	0·95	0·83	0·77	0·71	0·59	0·53
Zinc	2·20	1·86	1·59	1·33	1·22	1·06	0·95	0·84	0·76	0·68	0·61	0·53	0 49	0·46	0·38	0·34
Monel	2·66	2·26	1·93	1·69	1·48	1·31	1·16	1·03	0·94	0·84	0·74	0·65	0·61	0·56	0·49	0·47
Aluminium	0·73	0·64	0·56	0·48	0·42	0·37	0·33	0·29	0·26	0·24	0·21	0·18	0·17	0·16	0·14	0·13

WEIGHT OF SQUARE AND ROUND STEEL BARS

For Iron deduct 2 per cent

Table shows weight per foot run

Diameter or Side	Square	Round	Diameter or Side	Square	Round
in.	lb.	lb.	in.	lb.	lb.
1/8	·053	·042	1 3/4	10·4	8·19
3/16	·120	·894	1 13/16	11·2	8·78
1/4	·213	·167	1 7/8	12·0	9·39
5/16	·332	·261	1 15/16	12·8	10·0
3/8	·479	·376	2	13·6	10·7
7/16	·651	·511	2 1/8	15·4	12·0
1/2	·851	·658	2 1/4	17·2	13·6
9/16	1·08	·845	2 3/8	19·2	15·1
5/8	1·33	1·04	2 1/2	21·3	16·8
11/16	1·61	1·29	2 5/8	23·5	18·4
3/4	1·91	1·50	2 3/4	25·7	20·2
13/16	2·25	1·77	2 7/8	28·1	22·1
7/8	2·61	2·04	3	30·6	24·1
15/16	2·99	2·35	3 1/4	35·9	28·3
1	3·40	2·68	3 1/2	41·7	32·8
1 1/16	3·84	3·02	3 3/4	47·8	37·6
1 1/8	4·31	3·38	4	54·4	42·8
1 3/16	4·80	3·77	4 1/4	61·5	46·3
1 1/4	5·32	4·17	4 1/2	68·9	54·1
1 5/16	5·86	4·61	4 3/4	76·8	60·3
1 3/8	6·43	5·05	5	85·1	66·9
1 7/16	7·03	5·19	5 1/4	93·8	73·7
1 1/2	7·71	6·01	5 1/2	102·9	80·9
1 9/16	8·31	6·52	5 3/4	112·4	88·4
1 5/8	8·99	7·05	6	122·5	96·2
1 11/16	9·80	7·62			

WEIGHT, MELTING POINT, AND SPECIFIC HEAT OF METALS

Metal	Weight Lb./cub. ft.	Melting Point ° F.	Specific Heat
Aluminium	167	1,210	·219
Brass	537	1,850	·092
80 copper, 20 zinc / 50 copper, 50 zinc	512	Approx. 1,700	—
Bronze	532	Approx. 1,675	
Cast Iron	450	2,200	·114
Copper	550	1,940	·0936
Lead	709	620	·0305
Monel	554	2,480	—
Nickel	540	2,600	·109
Steel	490	2,500	·116
Tin	455	446	·0553
Zinc	428	785	·0935

CASTING WEIGHT FROM PATTERN

Material	Weight of Casting per Lb of Pattern (approx.)						
	C.I	C.S.	Zn	Cu.	Y B	G.M.	Al.
Baywood	12	14	12	15	14 5	15	4 5
Beech	10	11	10	12	11 5	12	3 5
Cedar	11 5	12 5	11 5	13 5	13	13 5	3 7
Mahogany	8	9	8	10	9 5	10	3 0
Maple	10	11	10	12 5	12	12 5	3 5
Oak	8	9	8	10	9 5	10	3 0
White Pine	14 5	15 5	14 5	18	17 5	18	5 5
Yellow Pine	14	15	14	17	16 5	17	5 0

The patterns are without cores C I, cast iron, C S cast steel, Y B, yellow brass, G M. gun metal.

WEIGHTS OF VARIOUS SUBSTANCES

Material	Lb /cu ft	Cu ft /ton	Material	Lb /cu ft	Cu ft /ton
Brick (common)	85 118	26¼ 19	Gravel and Sand (dry)	100	22½
,, (fire)	137	16⅓	Marble	168	13⅓
,, (in mortar)	112–125	20–18	Millstone	154	14½
Cement (loose)	85	26	Sand (very wet)	125	18
,, (set)	140	16	Slate	157–180	14¼ 12½
Chalk	145	15½	Stone, Bath	122	18⅓
Clay	120–135	18¾ 16½	,, Basalt	164	13⅔
Coal	77–102	29 22	Craigleith	145	15½
,, (common)	80	28	Lime	168	13⅓
Earth (common)	90 130	25 17¼	Paving	151	14¾
Granite	164	13⅔	Portland	145	15½
Gravel and Sand (moist)	110	20⅓	Sandstone	137	16⅓

Loose coal occupies approx 42 cub ft per ton

CEMENT AND CONCRETE COMPRESSIVE STRENGTH AFTER A YEAR

Lime or Cement	Proportions of Lime or Cement to Sand and Gravel			
	1 to 6	1 to 8	1 to 10	1 to 12
Grey Lime	10 2	4 6	5 2	
Lias Lime	11 4	11 1	11 5	
Anberthan Lime	34 1	21 8	15 4	
Portland Cement	100 7	76 4	53 5	37 1

Cement: 12 bags = 1 ton, 1 bag = 187 lb or approx 1⅔ cwt
For 6 to 1 Portland Cement Concrete 1 cub ft = 136 lb, 1 cub yard = 1 64 tons, 16½ cub ft = 1 ton.
2 bags of cement for 1 cub. yd of concrete 3 cwt 2 qr 14 lb
Ultimate tensile strength of good cement concrete used as a beam is 100 lb. per sq. inch.

WHITWORTH STANDARD BOLTS AND NUTS

Diameter of bolt	Threads per inch	Diam. at Bottom of Thread	Area at Bottom of Thread	Width across Flats	Width across Corners	Thickness of Bolt Head	Thickness of Nut
In.		In.	Sq. in.	In.	In.	In.	In.
¼	20	·1860	·027	·525	·6062	·2187	¼
5/16	18	·2414	·046	·6014	·6944	·2734	5/16
⅜	16	·2950	·068	·7094	·8191	·3281	⅜
7/16	14	·3460	·094	·8204	·9473	·3828	7/16
½	12	·3933	121	·9191	1·0612	·4375	½
9/16	12	·4558	·164	1·011	1·1674	·4921	9/16
⅝	11	·5086	·203	1·101	1·2713	·5468	⅝
11/16	11	·5711	·256	1·2011	1·3869	·6015	11/16
¾	10	·6219	·304	1·3012	1·5024	·6562	¾
13/16	10	·6844	·367	1·39	1·6050	·7109	13/16
⅞	9	·7327	·422	1·4788	1·7075	·7656	⅞
1	8	·8399	·554	1·6701	1·9284	·875	1
1⅛	7	·9420	·697	1·8605	2·1483	·9843	1⅛
1¼	7	1·0670	·894	2·0483	2·3651	1·0937	1¼
1⅜	6	1·1616	1·06	2·2146	2·5571	1·2031	1⅜
1½	6	1·2866	1·3	2·4134	2·7867	1·3125	1½
1⅝	5	1·3689	1·472	2·5763	2·9748	1·4218	1⅝
1¾	5	1·4938	1·753	2·7578	3·1844	1·5312	1¾
2	4·5	1·7154	2·31	3·1491	3·6362	1·75	2
2¼	4	1·9298	2·925	3·546	4·0945	1·9687	2¼
2½	4	2·1798	3·732	3·894	4·4964	2·1875	2½
2¾	3·5	2·3841	4·464	4·181	4·8278	2·4062	2¾
3	3·5	2·6341	5·45	4·531	5·2319	2·625	3
3¼	3·25	2·8560	6·406	4·85	5·6002	2·843	3¼
3½	3·25	3·1060	7·577	5·175	5·9755	3·062	3½
3¾	3	3·3231	8·673	5·55	6·4085	3·281	3¾
4	3	3·5731	10·027	5·95	6·8704	3·5	4
4½	2·875	4·0546	12·912	6·825	7·8819	3·937	4½
5	2·75	4·534	16·15	7·8	9·0066	4·375	5

SAFE LOADS ON STUDS AND BOLTS

(General Engineering = *G*. Hydraulic Engineering = *H*)

Diameter of Stud or Bolt Inches	Safe Load that One Stud or Bolt will Carry (Mild Steel) *G.* *H.*	Diameter of Stud or Bolt Inches	Safe Load that One Stud or Bolt will Carry (Mild Steel) *G.* *H.*
	Lb.		Lb.
½	400 550	1¾	10,500—15,600
⅝	800— 1,000	2	16,200—20,800
¾	1,100— 1,250	2½	26,100
⅞	1,600— 2,530	3	38,100
1	2,600 – 3,300	3½	53,000
1⅛	3,500— 4,800	4	70,200
1¼	4,500— 8,000	4½	90,000
1⅜	6,000— 8,500	5	113,000
1½	7,500—10,500	5½	138,000

BRITISH STANDARD PIPE THREADS

Int. Dia.	Ext. Dia. Black Tube (approx.)	Dia. at Top of Thread	Depth of Thread	Dia. at Bottom of Thread	Area at Bottom of Thread	Threads per inch
in.	in.	in.	in.	in.	sq. in.	
1/8	13/32	·383	·023	·337		28
1/4	17/32	·518	·0335	·451	·1598	19
3/8	11/16	·656	·0335	·589	2725	19
1/2	27/32	·825	·0455	·734	4232	14
5/8	15/16	·902	·0455	·811	·5166	14
3/4	1 1/16	1·041	·0455	·950	·7088	14
7/8	1 7/32	1·189	·0455	1·098	·9469	14
1	1 11/32	1·309	·058	1 193	1·1178	11
1 1/4	1 11/16	1·650	·058	1·534	1·8482	11
1 1/2	1 29/32	1·882	·058	1·766	2·4495	11
1 3/4	2 5/32	2·116	·058	2·000	3·1416	11
2	2 3/8	2·347	·058	2·231	3·9092	11
2 1/4	2 5/8	2·587	·058	2·471	4·7955	11
2 1/2	3	2·960	·058	2·844	6·3526	11
2 3/4	3 1/4	3·210	058	3·094	7·5185	11
3	3 1/2	3·460	·058	3·344	8·7826	11
3 1/4	3 3/4	3·700	058	3·584	10·0877	11
3 1/2	4	3·950	·058	3·834	11·5450	11
3 3/4	4 1/4	4·200	·058	4·084	13·0997	11
4	4 1/2	4·450	·058	4·334	14·7526	11
4 1/2	5	4·950	·058	4·834	18·3528	11
5	5 1/2	5·450	·058	5·334	22·3458	11
5 1/2	6	5·950	·058	5·834		11
6	6 1/2	6·450	·058	6·334		11

STANDARD WATER PIPE FLANGES FOR RADIATORS

Ext. Dia.	Bolt Hole Centres	Flange Length	Flange Width	Flange-End Radius	Flange-Cen. Radius	Bolt Hole Dia.	Bolt Dia.	Flange Thickness
in.	in.	in.	in.	in.	in.	in.	in.	in.
1 1/4	2 1/4	3	1 3/4	1/2	7/8	11/32	5/16	3/8
1 1/2	2 5/8	3 3/8	2	1/2	1	11/32	5/16	3/8
1 3/4	3	4	2 1/4	5/8	1 1/8	13/32	3/8	7/16
2	3 1/4	4 1/4	2 1/2	5/8	1 1/4	13/32	3/8	7/16
2 1/4	3 1/2	4 1/2	2 3/4	3/4	1 3/8	13/32	3/8	1/2
2 1/2	3 3/4	4 3/4	3 1/4	3/4	1 5/8	13/32	3/8	1/2
2 3/4	4	5	3 1/2	3/4	1 3/4	13/32	3/8	1/2
3	4 1/2	5 3/4	3 3/4	7/8	1 7/8	15/32	7/16	9/16
3 1/4	4 3/4	6	4	7/8	2	15/32	7/16	9/16
3 1/2	5	6 1/4	4 1/4	7/8	2 1/8	15/32	7/16	9/16

B.S. FINE THREADS

Diam.	Threads per in.	Depth of Thread	Dia. at Bottom of Thread	Area at Bottom of Thread
in.		in.	in.	sq. in
1/4	26	·02465	·2007	·0316
9/32	26	·02465	·2320	·0423
5/16	22	·02910	·2543	·0508
3/8	20	·03200	·3110	·0760
7/16	18	·03555	·3664	·1054
1/2	16	·04000	·4200	·1385
9/16	16	·04000	·4825	·1828
5/8	14	·04575	·5335	·2235
11/16	14	·04575	·5960	·2790
3/4	12	·05335	·6433	·3250
13/16	12	·05335	·7058	·3913
7/8	11	·05820	·7586	·4520
15/16	11	·05820	·8211	·5295
1	10	·06405	·8719	·5971
1 1/8	9	·07115	·9827	·7585
1 1/4	9	·07115	1·1077	·9637
1 3/8	8	·08005	1·2149	1·1593
1 1/2	8	·08005	1·3399	1·4100
1 5/8	8	·08005	1·4649	1·6854
1 3/4	7	·09150	1·5 70	1·9285
1 7/8	7	·09150	1·6920	2·2485
2	7	·09150	1·8170	2·5930
2 1/8	7	·09150	1·9420	2·9620
2 1/4	6	·10670	2·0366	3·2576
2 3/8	6	·10670	2·1616	3·6698
2 1/2	6	·10670	2·2866	4·1065
2 5/8	6	·10670	2·4116	4·5677
2 3/4	6	·10670	2·5366	5·0535
2 7/8	6	·10670	2·6616	5·5639
3	5	·12805	2·7439	5·9133

STANDARD CARBURETTOR FLANGES (2 Bolt Type)

Flange No.	Carburettor Bore	Max. Bore	Bolt Hole Centres	Flange Length	Flange Width	Flange-End Radius	Flange-Cen. Radius	Bolt Hole Dia.	Bolt Dia.
	m.m.	m.m.	m.m.	m.m.	m.m.	m.m.	m.m.	m.m.	in.
B.S.1	To 26	26	48	62	38	10	19	7·0	1/4
B.S.2	27–30	30	55	73	45	12	22·5	8·5	5/16
B.S.3	31–36	36	65	85	52	13	26	10·5	3/8
B.S.4	37–42	42	72	96	58	15	29	10·5	3/8
B.S.5	43–48	48	76	100	65	15	32·5	10·5	3/8
B.S.6	9–55	55	82	106	72	15	36	10·5	3/8

S.A.E. STANDARD SCREW THREADS

Diameter	Threads per inch	Core Diameter	Core Area	Tap Drill Size
in.		in.	sq. in.	in.
$\frac{1}{4}$	28	0·2036	0·0325	No. 5
$\frac{5}{16}$	24	0·2584	0·0524	$\frac{17}{64}$
$\frac{3}{8}$	24	0·3209	0·0808	$\frac{21}{64}$
$\frac{7}{16}$	20	0· 726	0·109	$\frac{3}{8}$
$\frac{1}{2}$	20	0·4351	0·149	$\frac{7}{16}$
$\frac{9}{16}$	18	0·4903	0·189	$\frac{1}{2}$
$\frac{5}{8}$	18	0·5528	0·240	$\frac{9}{16}$
$\frac{11}{16}$	16	0·6063	0·289	$\frac{39}{64}$
$\frac{3}{4}$	16	0·6688	0·351	$\frac{43}{64}$
$\frac{7}{8}$	14	0·7822	0·481	$\frac{51}{64}$
1	14	0·9072	0·647	$\frac{59}{64}$
$1\frac{1}{8}$	12	1·0168	0·812	$1\frac{1}{32}$
$1\frac{1}{4}$	12	1·1418	1·024	$1\frac{5}{32}$
$1\frac{3}{8}$	12	1 2668	1·261	$1\frac{9}{32}$
$1\frac{1}{2}$	12	1·3918	1·524	$1\frac{13}{32}$

B.A. SCREW THREADS

No.	Diameter		Pitch		Core Area	Tapping		
						Core Diameter		Drill No.
	mm.	in.	mm.	in.	sq. mm.	mm.	in.	
0	6·0	·236	1·00	·0394	18·10	4 8	189	12
1	5·3	·209	·90	·0354	13 99	4 22	·166	19
2	4·7	·185	·81	·0319	10 93	3 73	147	26
3	4·1	·161	·73	0287	8·14	3 22	127	31
4	3·6	·142	·66	0260	6·20	2 81	111	34
5	3·2	·126	59	·0232	4 87	2 49	098	40
6	2·8	·110	·53	·0209	3·66	2 16	·085	44
7	2·5	·098	·48	·0189	2·89	1 92	·076	48
8	2·2	·087	·43	·0169	2·22	1·68	·066	51
9	1·9	·075	·39	·0154	1·61	1 43	·057	53
10	1·7	·067	·35	·0138	1 29	1 28	·050	56
11	1 5	·059	31	·0122	1·00	1·13	·044	59
12	1·3	·051	·28	·0110	0·72	0 96	·038	62
13	1·2	·047	25	0098	0 64	0 90	·035	65
14	1·0	·039	·23	·0091	0·41	0·72	·028	70
15	0·90	·035	21	·0083	0·33	0·65	·025	72
16	0·79	·031	·19	·0075	0 25	0·56	·022	74
17	0·70	·028	17	·0067	0 20	0 50	·020	76
18	0·62	·024	·15	·0059	0 15	0·44	·017	77
19	0·54	·021	·14	·0055	0 11	0 37	·015	78
20	0·48	·019	12	·0047	0·091	0·34	·013	80
21	0·42	·017	11	·0043	0 066	0 29	·011	—
22	0·37	·015	·10	·0039	0·049	0·25	010	
23	0·33	·013	·09	·0035	0·038	0·22	·009	
24	0·29	·011	·08	·0031	0·028	0·19	·008	

ATOMIC OR COMBINING WEIGHTS OF THE ELEMENTS

Element	Symbol	Atomic Weight	Element	Symbol	Atomic Weight
Aluminium	Al	27	Molybdenum	Mo	95.8
Antimony	Sb	119.6	Nickel	Ni	58.6
Arsenic	As	74.9	Niobium	Nb	94
Barium	Ba	136.8	Nitrogen	N	14.01
Beryllium	Be	9.1	Osmium	Os	195
Bismuth	Bi	207.5	Oxygen	O	15.96
Boron	B	10.9	Palladium	Pd	106.2
Bromine	Br	79.76	Phosphorus	P	30.96
Cadmium	Cd	111.7	Platinum	Pt	194.5
Cæsium	Cs	132.7	Potassium	K	39.03
Calcium	Ca	39.9	Rhodium	Rh	104.1
Carbon	C	11.97	Rubidium	Rb	85.2
Cerium	Ce	141.2	Ruthenium	Ru	103.5
Chlorine	Cl	35.37	Scandium	Sc	44
Chromium	Cr	52.4	Selenium	Se	78.9
Cobalt	Co	58.6	Silicon	Si	28
Copper	Cu	63.2	Silver	Ag	107.66
Didymium	D	145	Sodium	Na	22.99
Erbium	E	166	Strontium	Sr	87.3
Fluorine	F	19.06	Sulphur	S	31.98
Gold	Au	196.2	Tantalum	Ta	182
Hydrogen	H	1	Tellurium	Te	126.3
Indium	In	113.4	Thallium	Tl	203.6
Iodine	I	126.54	Thorium	Th	232
Iridium	Ir	192.5	Tin	Sn	117.5
Iron	Fe	55.9	Titanium	Ti	48
Lanthanum	La	138.5	Tungsten	W	183.6
Lead	Pb	206.4	Uranium	Ur	239.8
Lithium	Li	7.01	Vanadium	V	51.2
Magnesium	Mg	23.94	Yttrium	Y	89.6
Manganese	Mn	54.8	Zinc	Zn	64.88
Mercury	Hg	199.8	Zirconium	Zr	90

IMPERIAL OR LEGAL STANDARD WIRE GAUGE

Descriptive Number	Equivalent in Parts of an Inch	Equivalent in Millimetres	Sectional Area of Wire in Sq. In.	Descriptive Number	Equivalent in Parts of an Inch	Equivalent in Millimetres	Sectional Area of Wire in Sq. In.
7/0	·500	12·700	·1963	23	·024	·610	·0005
6/0	·464	11·785	·1691	24	·022	·559	·0004
5/0	·432	10·973	·1466	25	·020	·508	·0003
4/0	·400	10·160	·1257	26	·018	·457	·00025
3/0	·372	9·449	·1087	27	·0164	·4166	·00021
2/0	·348	8·839	·0951	28	·0148	·3759	·00017
0	·324	8·229	·0824	29	·0136	·3454	·00015
1	·300	7·620	·0707	30	·0124	·3150	·00012
2	·276	7·010	·0598	31	·0116	·2946	·00011
3	·252	6·401	·0499	32	·0108	·2743	·00009
4	·232	5·893	·0423	33	·0100	·2540	·00008
5	·212	5·385	·0353	34	·0092	·2337	·00007
6	·192	4·877	·0290	35	·0084	·2134	·00006
7	·176	4·470	·0243	36	·0076	·1930	·00005
8	·160	4·064	·0201	37	·0068	·1727	·00004
9	·144	3·658	·0163	38	·0060	·1524	·00003
10	·128	3·251	·0129	39	·0052	·1321	·00002
11	·116	2·946	·0106	40	·0048	·1219	·000018
12	·104	2·642	·0085	41	·0044	·1118	·000015
13	·092	2·337	·0066	42	·0040	·1016	·000013
14	·080	2·032	·0050	43	·0036	·0914	·000010
15	·072	1·829	·0041	44	·0032	·0813	·000008
16	·064	1·626	·0032	45	·0028	·0711	·000006
17	·056	1·422	·0025	46	·0024	·0610	·000004
18	·048	1·219	·0018	47	·0020	·0508	·000003
19	·040	1·016	·0013	48	·0016	·0406	·000002
20	·036	·914	·0010	49	·0012	·0305	·000001
21	·032	·813	·0008	50	·0010	·0254	·000001
22	·028	·711	·0006				

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